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RAILWAY SIGNALING

A Comprehensive Treatise on Modern Methods of Railway Signaling, covering Principles of Operation and Types of Apparatus

Written by a Staff of Expert
Signal Engineers

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Preface

The lack of any adequate literature on the subject of Railway Signaling was called to the attention of the editors of THE ELECTRIC JOURNAL about two years ago, when an attempt was made to secure some information on the subject. On looking over such material as was available it was found that there were no publications giving a logical treatment of the subject in the present state of the art. It was, therefore, thought quite worth while to undertake the publication of a comprehensive series of articles along this line. An outline, covering the subject, was prepared and permission was finally obtained from the management of The Union Switch & Signal Company to have a number of their engineers prepare a series of articles for the JOURNAL. In this way it has been possible to obtain at first hand the latest and most authoritative information from men who are making a life study of the subjects which they treat and who are closely in touch with the latest developments in signaling. In describing the various principles of operation and types of apparatus, many of which appear very complicated, especially in installations of large size, the effort has been to make the reading pages and illustrations easily understood by the average reader. In many cases special illustrations have been prepared to show the operation of apparatus in principal rather than in detail.

It is believed that the following pages will prove of much value to all who are interested in railway work.

The following men, engineers of The Union Switch & Signal Company, are entitled to much credit for the painstaking manner in which they have handled their particular subjects: T. George Willson, Interlocking Engineer; W. H. Cadwallader, Signal Engineer; John D. Taylor, Assistant Electrical Engineer; T. H. Patenall, Signal Engineer; W. E. Foster, Engineering Assistant to the General Manager; J. B. Struble, Assistant Electrical Engineer.

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CHAPTER I

MECHANICAL INTERLOCKING

AN interlocking plant consists of a group of levers concentrated at a central point for operating certain switches and signals, and so arranged as to interlock such levers and make it impossible to give clear signals for conflicting routes. The advantages derived therefrom are safety, facility of operation and saving in cost of manual labor employed.

It is the purpose of this article to give, as briefly as possible, a general outline of what is accomplished by interlocking, the manner in which the work is done, and the construction of a particular type of machine.

TYPES OF MACHINES

As has been intimated, various types are in use, and they may be divided into classes as follows: Mechanical, hydro-pneumatic, electro-pneumatic, pneumatic, and electric.

Each style of machine is known by the kind of power utilized to perform the various functions for which it was designed, and as all were designed for the purpose of doing a certain kind of work, a description of the original (mechanical) machine, will give not only the method of operation peculiar to itself, but also a general idea of the principle of interlocking as used in all machines.

An interlocking machine may be small in size, that is, may have but few levers, sufficient to properly protect a single track grade crossing; or it may be to take care of a crossover between the tracks of a double track road; or to protect a junction point where two single track roads converge. Or, on the other hand, the machine may be a large one, with many levers, sufficient to properly handle a grade crossing where several roads cross other roads, and perhaps having interchange tracks; or, it may be for handling a large classification yard, a large passenger terminal, or a combination of any of the above. Therefore, the size of machine depends entirely upon the arrangement of tracks at the point to be protected.

METHOD OF SIGNALING A PLAN OF TRACKS

When it is desired to install an interlocking plant, the first thing is to have a plan of tracks, which is then signalled up, that is, all

the switches to be operated are noted; the derails, signals, tower, and run of connections are located; the size of machine and func-

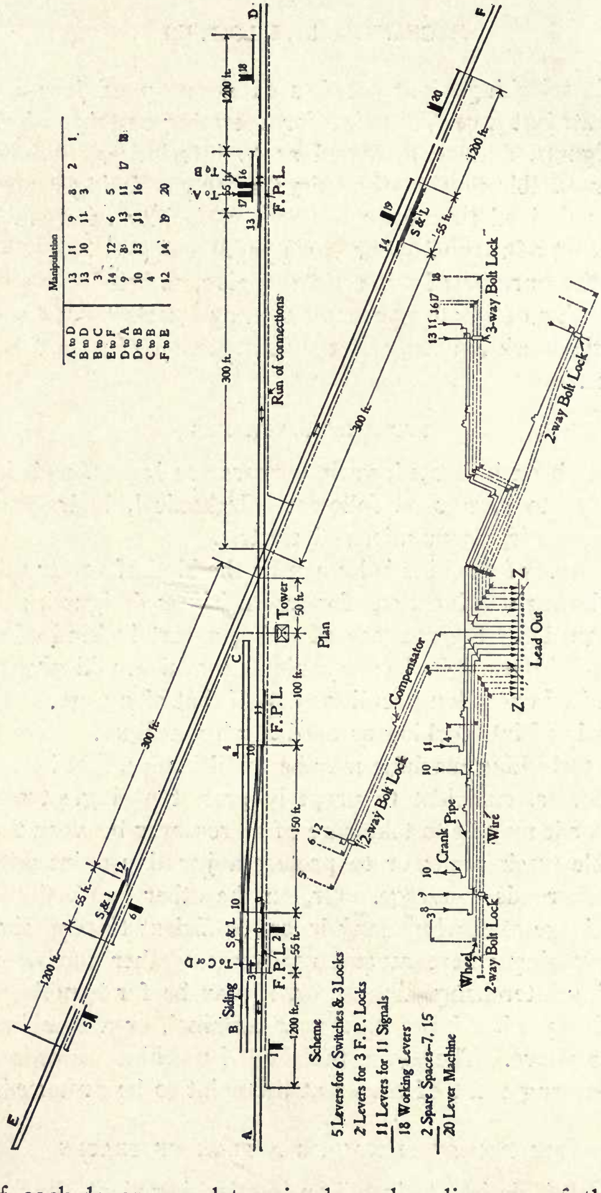


FIG. I—TYPICAL RAILROAD CROSSING PROTECTED BY A MECHANICAL INTERLOCKING PLANT

tions of each lever are determined; and a diagram of the leadout made, as illustrated by Fig. 1. From the signalled plan, a locking

sheet is then made, that is, the proper interlocking to be done between levers is determined, as illustrated by the locking sheet in Fig. 5. From the locking sheet, a dog sheet is made, this being a diagram which shows the arrangement of the interlocking parts as they are to be placed in the machine. This is illustrated by the dog sheet in Fig. 5.

The plan, as shown on Fig. 1, is a typical layout of tracks, showing a grade crossing protected by derails, and a siding connected with one of the main tracks by a crossover. At each switch or derail a signal is located to govern movements over the point where the tracks intersect. The numbers shown at each switch, derail, signal, etc., mean that that particular switch, derail, signal, etc., is to be operated by a lever in the machine having the same number. That is, lever *1* will control signal *1,* lever *9* derail *9,* etc. By referring to the scheme, it will be found that eighteen levers will be required to operate this plant, but as mechanical machines are built up of four lever sections, a machine will be used having eighteen working levers and two spare spaces, the latter being available for levers in case it be necessary to make an addition to the plant at some future time.

When no movements are being made over the crossing, all derails are open, the switch on the siding set for the stub end, and all signals are in the horizontal (danger; stop) position, and when in such position, they are known as being *normal* and the levers in the machine are normal also. When a derail is closed, a switch thrown, or a signal cleared, they are then known as being in the *reverse* position, and the lever by which the operation is performed is then also known as being in the reverse position.

When a movement is desired over any one of the tracks, it is necessary to set all switches and derails in the right position for such movement, then lock them in such position, after which the signal governing traffic over that particular track may be cleared. Under the head of *"Manipulation"* in Fig. 1, is a table showing just what levers are to be reversed to allow movements over the various routes. For example, in order to allow a train to go from *A* to *D,* levers *13-11-9-8-2* and *1* must be reversed in the order named, and the last lever reversed locks all of the preceding ones. The closing of either derail in the route will lock the derails of conflicting routes normal, they in turn will hold the signals normal. Therefore it will be seen that where two or more routes conflict, the signals of but one can be cleared.

SWITCHES AND DERAILS

A switch is used to deflect traffic from one track to another. A derail is in reality a switch, and is also used for deflecting traffic, but not from one track to another, for as its name implies, its purpose is to derail, or deflect from the rails onto the ties, or ground, or into some short track or obstruction, in order to stop traffic if the signal be disregarded. Nos. *9-12-13-14* in Fig. 1 represent derails. They operate in such a way that if, for any reason, an engineer attempts to take his train over a crossing when the signal governing the movement is normal (stop) his train will be derailed, and as the derails are located 300 feet from the crossing, the train would not reach the tracks of the other road, (which may be occupied by another train), even though it may have been moving at high speed before leaving the rails. Although derails will accomplish this, it is not expected or desired that this should occur, and it very rarely happens for the reason that, if an engineer knows his train will be derailed if he attempts to pass a signal at danger, he will be very careful to stop at the signal.

THE DETECTOR BAR

At each switch is a bar which lies against the outside of the rail, and is so adjusted that the top of the bar, when in the normal position, is three-eights of an inch below the top of the rail. This is what is known as a detector bar, and works in conjunction with the lock on a switch, so that when a movement is being made over a switch, the wheels will prevent the bar from being raised, thus preventing the leverman from unlocking the switch when a train is passing over it. Before a train movement can be made, all switches, after having been set in the proper position, must be locked. This is done by a bolt or dog being thrust through a notch or hole in a bar connected to the points of the switch. If for any reason the switch points do not go to the proper place when the lever by which the switch is operated is thrown, it is obvious that the bolt or dog cannot be thrust through the bar and the switch cannot be locked, thus indicating to the leverman that the switch is not in proper position.

METHOD OF LOCKING SWITCHES AND DERAILS

A switch may be moved and also locked by a single lever. When this is done, a mechanism called a switch and lock movement

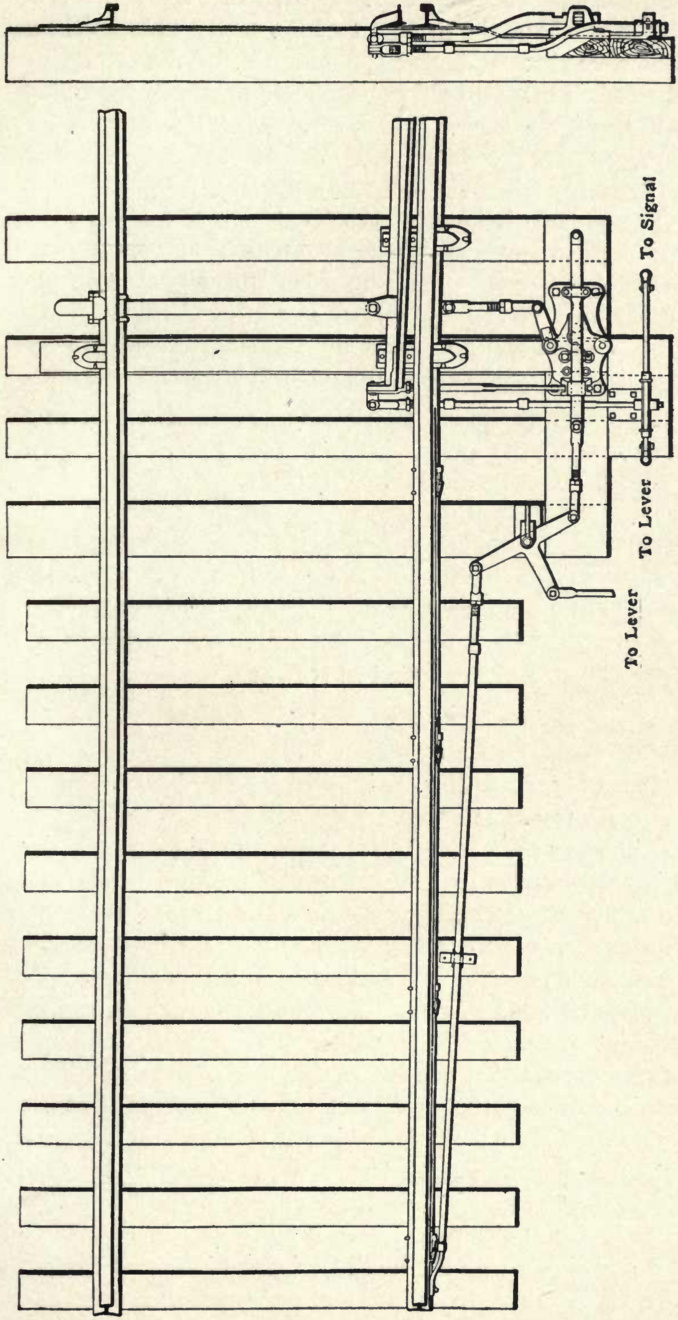


FIG. 2—SWITCH AND LOCK MOVEMENT WITH BOLT LOCK APPLIED TO DERAIL

is used, it being located opposite the switch. When actuated by a lever in the machine, the first part of the stroke unlocks the switch, the mid-stroke throws it, and the last part of the stroke locks it. Thus the switch is locked either normal or reversed, depending upon the position of the lever. When such a device is used, on main tracks, the signals governing movements over such tracks are also made to lock the switch by means of what is called a bolt lock, which makes it impossible for a signal to be cleared if for any reason the switch is not in the proper position. Fig. 2 illustrates a switch and lock movement with bolt lock applied to a derail.

While some roads use switch and lock movements on main tracks, most roads use them only for the siding end of cross-overs, or for derails on unimportant sidings, preferring the use of a separate lever to operate the locks on main line switches. When a separate lever is used, the lock is called a facing point lock, getting its name from the fact that originally a switch was locked only when traffic was to be given the right of way in the direction facing the switch point, but present practice is to lock all switches whether traffic be facing the points or trailing. Some roads also use a bolt lock, operated by the signal, as an additional precaution, even when a switch is locked by a facing point lock. Fig. 3 shows a facing point lock with bolt lock applied to a switch.

FORM OF SIGNALS

Referring again to Fig. 1, it will be noticed that all signals located on main tracks are shown high and the two located on siding are low, it being the general practice to use high signals for main tracks, in the direction of ordinary traffic, and low or dwarf signals for movements on or out of sidings or against traffic on main tracks. A high signal with square end blade is called a home signal; with the end of blade notched, it is known as a distant signal. A distant blade horizontal means *caution,* that the home signal in advance of it may be at danger. When a distant blade is inclined, it means *clear,* and indicates that the home signal is clear also. Therefore, if an engineer approaches a distant signal and finds it at clear, he may proceed at high speed, knowing that the main line route has been set up and ready for him to proceed without a stop; but if he finds the distant at caution, he must approach the home signal expecting to find it at danger.

A dwarf signal with the blade horizontal indicates danger, stop; with the blade inclined, indicates clear, proceed slowly, as move-

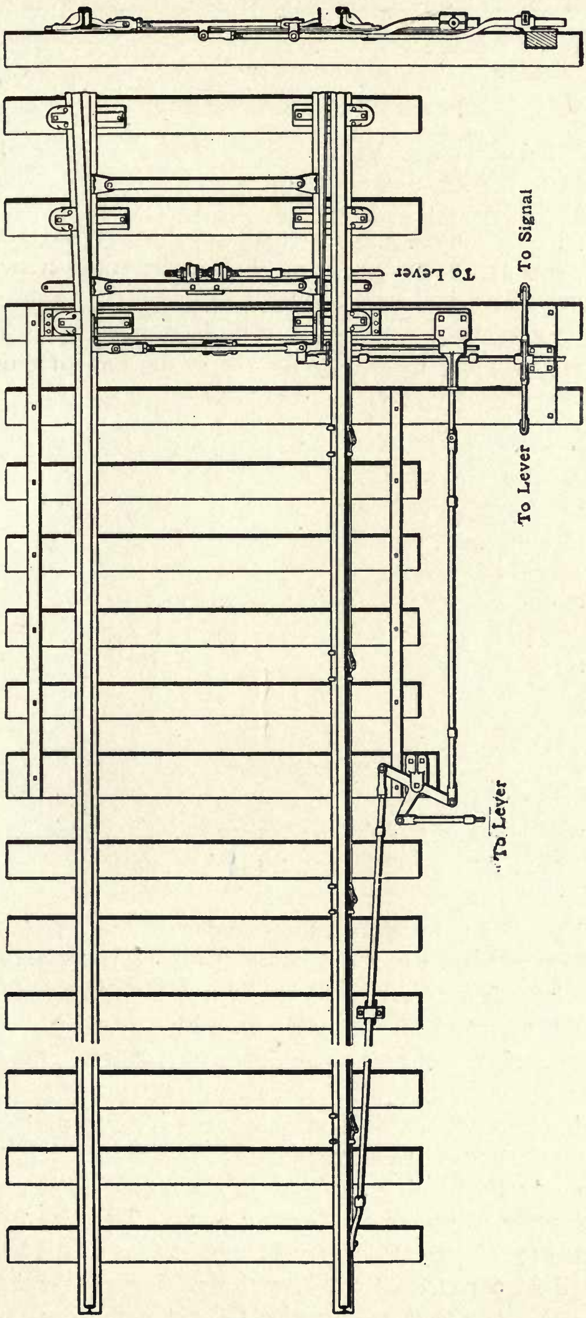


FIG. 3—FACING POINT LOCK WITH BOLT LOCK APPLIED TO SWITCH

ments on or out of a siding or against traffic on main tracks necessarily should be made cautiously.

DETAILS OF CONSTRUCTION

The dotted lines in Fig. 1 leading from the tower along the tracks, indicate the location of the pipe and wire connections from the machine to the various switches, signals, etc., these connections being shown in detail under the heading *Leadout.* In the leadout each full line represents a single line of pipe, and each dotted line represents two wires, each line having a number corresponding to its operating lever. Pipe lines are supported by roller carriers on wood, iron or concrete foundations, placed every seven feet, and when such lines are over fifty feet long, a compensator (to take care of expansion and contraction due to changes in temperature) is used. Wire lines are supported in the same manner as pipe, except that the carriers are placed every twenty-one feet, and compensation is usually taken care of by adjusting screws located in the tower.

The letters *ZZ* on the leadout shown in Fig. 1 represent the point on Fig. 4, where the vertical cranks and wheels are located, and through which connection is made to the machine. In the majority of cases machines are located so as to be operated from the second floor of a tower, because it is desirable that a lever man shall have a good view of the tracks and signals. Some machines are built, however, to be operated from the ground floor.

All machines have the levers numbered consecutively, beginning with the left-hand end facing the levers. Mechanical machines may be divided into two classes, those having lever locking and those having latch (or preliminary) locking. The levers of all machines are provided with latches, the purpose of which is to keep the levers in the normal or reverse position. In a machine having lever locking, the latch is used for no other purpose than that stated above, the interlocking parts being actuated only by changing the position of the lever itself, which necessarily brings great strain on the locking parts, when an attempt be made to throw a lever when it is locked. Therefore, for such a machine, the locking parts must be made large and strong. In a machine having latch locking, the latch is used not only for holding the lever in the normal or reverse position, but also for actuating the locking parts. That is, these parts are connected to and operated by the latch, instead of the lever, thus permitting lighter construction. As the raising of the latch is a preliminary step to the throwing of a lever, the locking will there-

fore be accomplished before the lever moves from its position. This will be more readily understood by referring to Fig. 4, which shows a machine with the levers in the normal position. The machine illustrated is known as the Saxby & Farmer, a type generally used, not only because of the preliminary locking feature, but also because of the design of the locking parts. The parts of this machine by

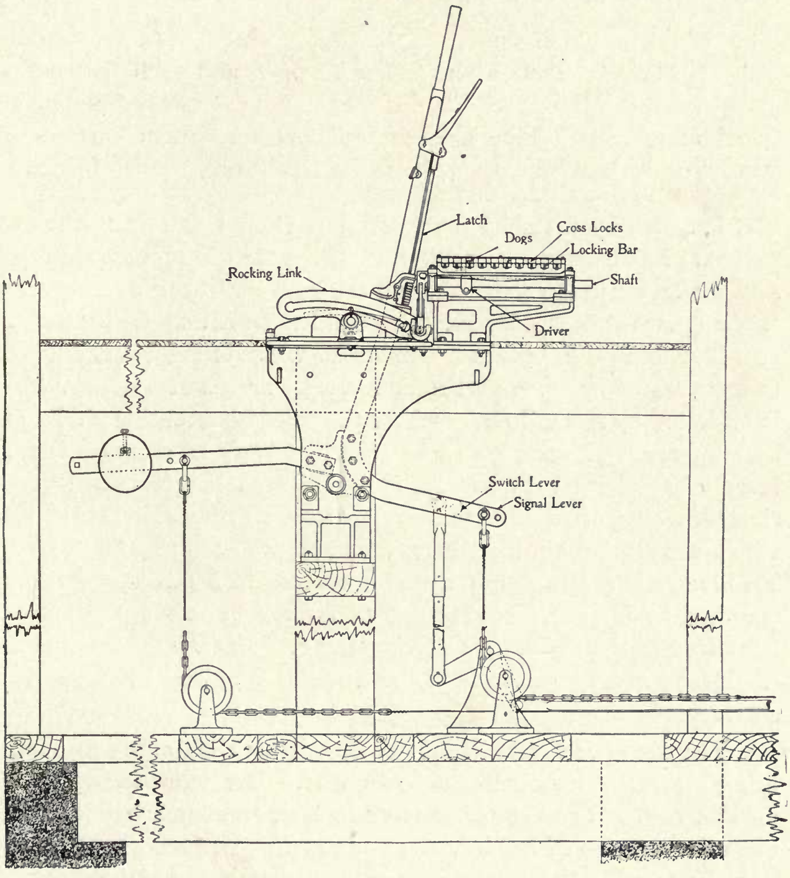


FIG. 4—END VIEW OF SAXBY AND FARMER INTERLOCKING MACHINE WITH CONNECTIONS AS LOCATED IN TOWER

which the interlocking between levers is accomplished, are known as the latch, rocking link, shaft, driver, bar, dogs and cross locks. See Fig. 4. When a latch is raised, a bar is moved a certain distance; to this bar dogs are riveted, which in turn drive the cross locks against other dogs which are riveted to bars operated by other

latches. With a lever in its normal position, the raising of the latch gives half of the necessary stroke to the bar, the remainder of which is given by dropping the latch after the lever has been reversed. As the same is true when throwing a lever from the reverse to the normal position, therefore, no matter in which position a lever stands, when the operation of moving it takes place, the first thing to happen is the raising of the latch, which accomplishes all of the locking, then occurs the movement of the lever, during which time no change in the locking takes place, last, the dropping of the latch which releases those levers which are to be thrown next.

Fig. 5 shows a locking and dog sheet, the former showing just what locking is desired, the latter showing the arrangement of the locking in the machine, this diagram being used not only for a record, but also by the shop men, for it is from this that the locking parts are constructed. The numbers at the top of the diagram represent the levers in the machine, and the heavy vertical lines represent shafts operated by the levers. The full length horizontal lines represent bars, each being given a number by which it is known, and each to be operated by some particular lever, by means of a driver, which is indicated by a small circle where the lines representing shafts and bars intersect. Hence it will be seen that lever *20* operates bar *19,* lever *9* bar *8,* lever *13* bar *18,* etc. On each bar certain dogs are riveted, which when a bar is moved, drives a cross-lock against dogs which are riveted on other bars, thus accomplishing certain locking. To illustrate, notice dog *a* which is riveted to bar *2,* the bar being operated by lever *2.* If the latch of lever *2* be raised, the bar will be moved to the right, thus driving the cross-lock *b* against the dog *c.* Hence *2* reversed, locks *17* normal, as required by the locking sheet.

The above is a very simple case, and is called straight locking, being a positive lock between two levers. The following is a more difficult one. For example, a lever to lock another lever depending upon the position of a third. Such an arrangement is shown on the dog sheet by *d-e-f-g-h.* It may be seen that if dog *d* be moved to the right when dog *e* is normal, dog *f* may be moved also, but if dog *e* first be moved to the right, thus filling the space between cross-locks *g* and *h,* then before the dog *d* can be moved, dog *f* must be moved, and when this is done, the moving of dog *d* drives the cross-lock *g* against dog *e,* and as this latter is a swing dog, through it the motion is communicated to the cross-lock *h,* which in turn is driven against dog *f,* and holds it in the reverse position so long

Locking Sheet

Lever Reversed	Locks
1	2
2	8 11 17
3	4 16 10 10
	11 w 10
4	10
5	6
6	12 14 19
7	Spare Space
8	9
9	10 12 14
10	12 14
11	10 10 13
12	13
13	14
14	—
15	Spare Space
16	11 10
17	11 8
18	17
19	14 12
20	19

Numbers without circle–Lever Normal

Numbers with circle–Lever Reversed

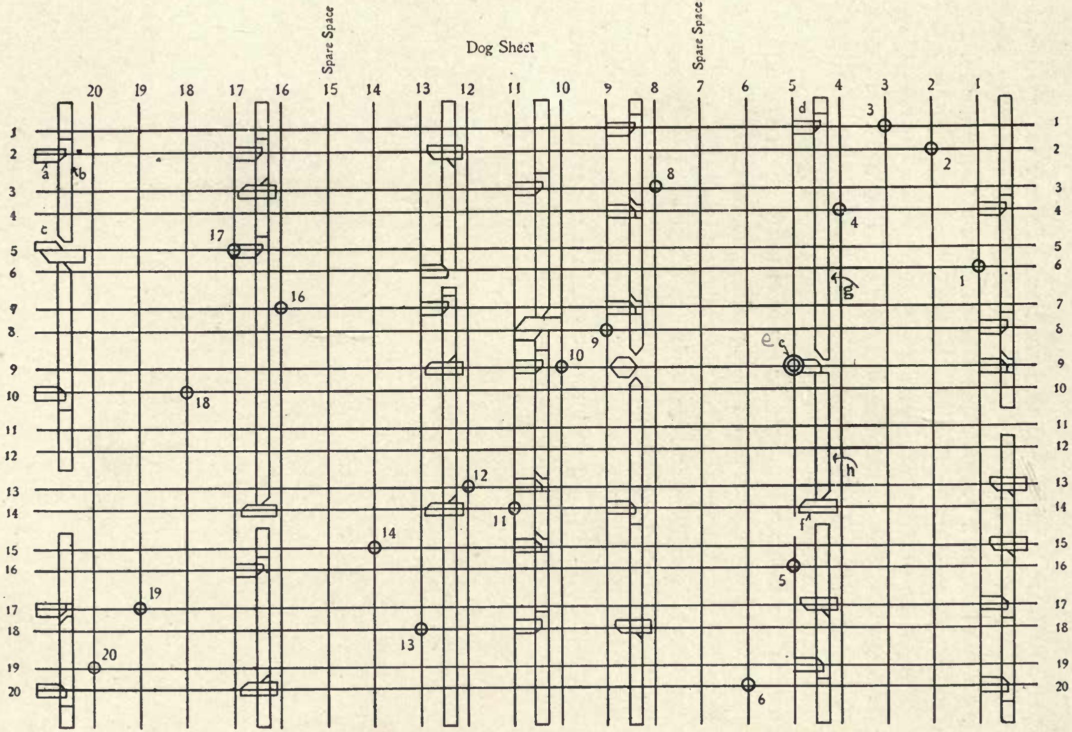


FIG. 5—LOCKING AND DOG SHEETS

as dogs *e* and *d* are kept in the same position. Thus *3* reversed locks *11* reversed when *10* is reversed, as required by the locking sheet. This is an example of a very simple case of special locking. In large machines it often happens that the locking between certain levers depends upon the position of perhaps ten or more other levers, and it is this feature which makes the arranging of the locks, as well as determining what locking is necessary, quite an engineering problem. It very seldom happens that any two machines are locked up exactly the same, as the locking required depends entirely upon the number and arrangement of tracks, and the signaling desired.

There are many special appliances and attachments, of both a mechanical and electrical nature, which are often used in connection with an interlocking machine such as has been described, but enough information has been given in this article to enable those who are unfamiliar with interlocking to understand, in a general way, one of the methods used to handle traffic safely and quickly.

CHAPTER II

ELECTRO-PNEUMATIC INTERLOCKING

AN interlocking system has been defined by the American Railway Association as "An arrangement of switch, lock and signal appliances so interchanged that their movements must succeed each other in a pre-determined order." The definition applies equally well to the mechanical and electro-pneumatic interlocking systems; the latter, however, possesses certain distinct advantages over the former, among the most important of which are the following:

1—It is fifty percent quicker in operation than the mechanical system, and at least ten percent quicker than any other power operated system at present in use, thus permitting extremely rapid train movements on congested tracks such as large terminals, elevated lines and subways.

2—The interlocking machine usually requires less than one-quarter of the space occupied by a mechanical machine for operating the same number of switches, locks, and signals, thus economizing in the size of the building or "tower" containing it.

3—As the small operating levers entail very little effort on the part of the leverman to manipulate them, and as less levers are required than in a mechanical plant, fewer levermen are necessary for the operation of large plants.

4—The space required for the pipe and wire lines between the levers and functions operated in mechanical plants can be used for other purposes where electro-pneumatic interlockings are installed, since the room occupied by the wire and cables between levers and functions is comparatively small, and where necessary these pipes and wires can be placed in underground conduits.

As an example of the foregoing the electro-pneumatic interlocking plant at the St. Louis Terminal of the Terminal Railroad Association of St. Louis may be cited. The machine for operating this plant which includes 44 double slip switches with movable point frogs, 65 single switches and 194 signals, is about 44 feet in length over all, and contains only 215 levers, of which 33 are not in use, being available for future additions to the plant; whereas, a mechanical plant to operate this terminal would have contained 528 levers, and been 245 feet long. Five levermen on the busiest shift

operate the electro-pneumatic machine, while not less than twenty men would have been required for a mechanical machine under similar conditions. The wires and compressed air pipes at the St. Louis Terminal are all placed underground, and are entirely out of the way, while, had a mechanical plant been installed, the Terminal Company would have had to purchase considerable extra land on which to run the connections.

GENERAL PRINCIPLES

Briefly outlined, the electro-pneumatic interlocking system provides for the operation of switches, locks and signals by compressed air and their control by electricity. This is effected by applying pneumatic cylinders to all such functions, and admitting and releasing compressed air to and from these cylinders by means of valves actuated by electro-magnets which are energized from batteries or generators located in the operating tower, the circuits being controlled by the manipulation of the levers in the interlocking machine. The movements of the switches and signals are in turn repeated back to the machine levers through circuit controllers located at the switches and signals and operated by them, thus electrically locking and unlocking the levers as the position of the switches and signals may necessitate. By these means positive indications are given that the movements of the switches and signals at all times correspond with the positions of their respective levers.

PRINCIPAL ITEMS

An electro-pneumatic interlocking plant includes the following:

1—The power plant, comprising the air compressors, cooling coils and reservoirs, the electric generators, switchboard and batteries.

2—The interlocking machine, comprising the operating levers, the mechanical locking, the electric circuit controllers, and the electric locks.

3—The operating tower, which contains the interlocking machine and such other devices as may be necessary for quickly communicating and obtaining information from other points. These are usually in the form of visible or audible indicators, telephones, and telegraph instruments.

The main battery and electric generators are frequently located in the lower story of the tower.

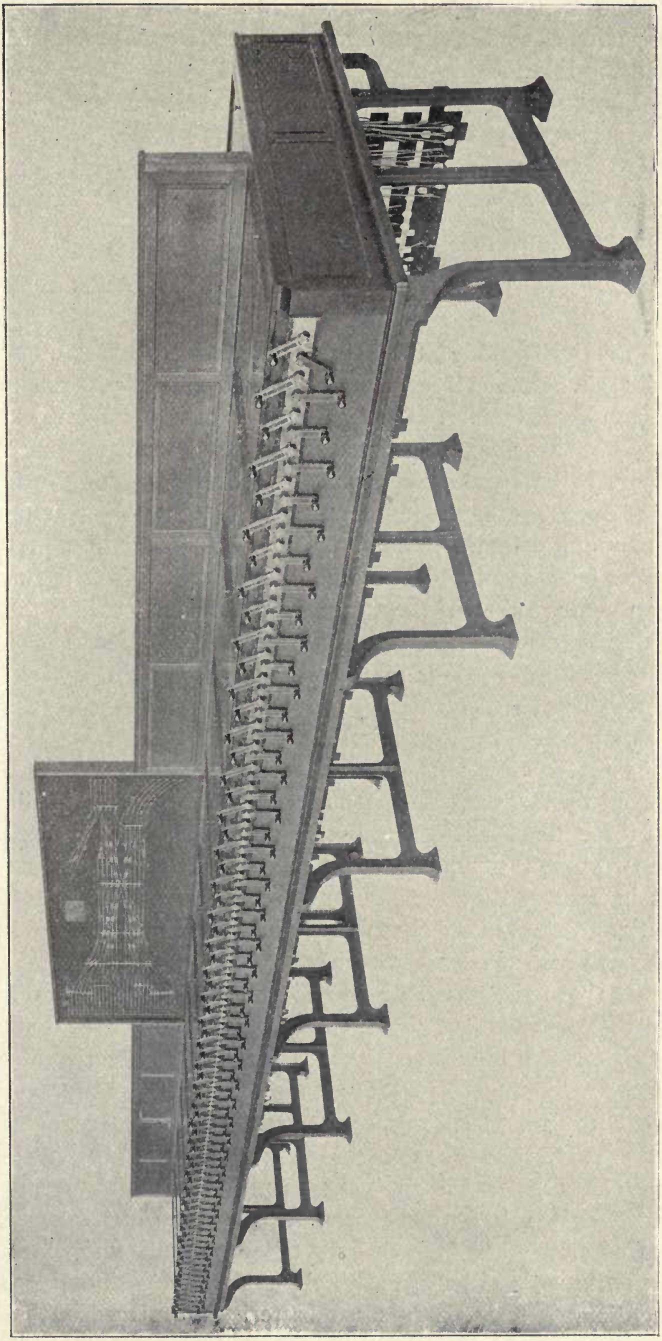


FIG. 6—VIEW OF ELECTRO-PNEUMATIC MACHINE AT BOSTON SOUTHERN STATION

4—The pneumatic connections between the compressing plant and the switches and signals, and the electric connections between them and the interlocking machine.

5—The functions, under which term the switches, locks and signals are generally referred to.

6—The auxiliary appliances, such as track circuits for the automatic control of signals and locks, gateman's indicators, annunciators, etc.

THE POWER PLANT

At practically all of the large terminals and at a number of other places where electro-pneumatic interlocking plants are in operation, compressed air is largely used for other purposes such as charging air brake tanks, cleaning cars and driving machinery. Consequently the pneumatic power for the interlocking plant can usually be taken from existing compressors. This air is first passed through cooling coils having a sufficiently large radiating surface to extract the heat generated by compression, and reduce the temperature of the air to that of the atmosphere before it reaches the main air pipe. Reservoirs of comparatively large capacity are placed below these cooling coils. These serve the double purpose of maintaining a reserve supply of air, should the compressor be stopped for a short time, and of collecting the moisture which has been condensed by the cooling coils. After leaving the cooling coils the air is conveyed by main pipes of from two to four inches in diameter through the entire system. The pipes are usually so arranged as to provide two paths by which the air can reach each switch or signal so that, in case of the breakage or stoppage of any pipe, the plant can continue to operate. Suitable expansion joints are provided to allow for variation in temperature.

From the main pipes, the air is conducted in smaller branch pipes to the switches and signals and at the end of each branch an auxiliary reservoir is located to catch whatever moisture may have escaped the main reservoirs. The main and auxiliary reservoirs are provided with cocks so that the water may be blown off from time to time.

The electrical power equipment usually consists of two small generators, driven by engines or motors, which alternately charge two sets of storage batteries of six or seven cells each, through a suitably designed switchboard. This equipment is located as convenience dictates, but as a rule, the batteries are placed in the lower

floor of the operating tower. The electrical power required by an electro-pneumatic plant is very small, the machine operating the largest plant in the world, St. Louis Terminal, Tower 1, requiring an average discharge of only five to six amperes.

INTERLOCKING MACHINE

In Fig. 6 is illustrated the Boston Southern Station Machine, from which a clear understanding can readily be had of its construction and method of operation. For the guidance of operators, especially when first learning the "combination" of large interlocking machines, it is customary to equip such machines with a miniature reproduction of the yard (known in signal parlance as a "Track Model") on which all switches and signals are

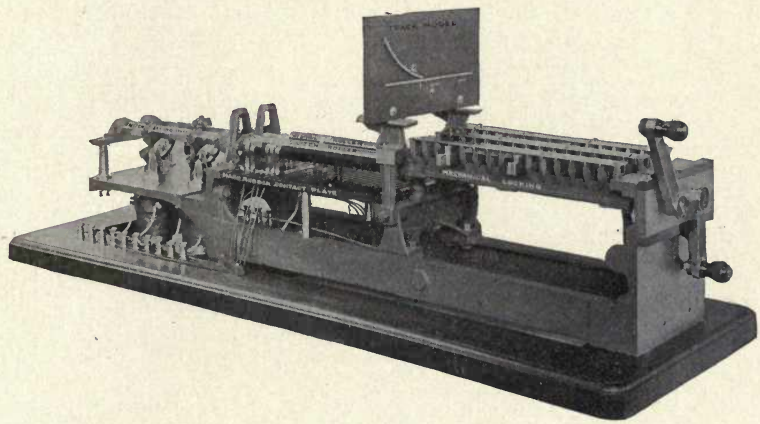


FIG. 7—SMALL MACHINE SHOWING MECHANICAL LOCKING, THE COMBINATION, THE INDICATION AND LOCK MAGNETS

numbered to correspond with the levers controlling them and all tracks are designated by their proper letters, names or numbers. The switches on this model board are connected mechanically to their controlling levers and move in accordance with them, thus permitting the operator to see at a glance the particular route or routes he has "lined up." On comparatively small plants having but few routes a track model is not necessary but on large and complicated installations it is of great assistance to the operators.

The operating levers point alternately up and down, those pointing upwards and having odd numbers being switch levers and the others signal levers. All machine levers are numbered from the left. Switch levers stand normally at an upward angle of 30 de-

grees to the left of the vertical, and when operated, are moved through an arc of 60 degrees. The normal position of signal levers is vertically downward from which they can be operated 30 degrees to the right or left, being capable of three distinct positions, the use of which will be explained later. A system of mechanical locks is provided between levers which is identical in every respect, except in size, with that described in a previous article treating of the mechanical interlocking machine. To each lever of the electro-pneumatic machine is secured a horizontal shaft, which performs three distinct functions. It drives the mechanical locking bars by means of racks and segmental gears; it rotates a hard rubber roller carrying phosphor bronze contact bands, thereby opening and closing the various controlling and selecting circuits for switches and signals; and lastly, it engages with the "indication latches" which are actuated by magnets, the energizing of which is effected by such switches and signals. Each switch lever is equipped with two such magnets, one known as the "normal" and the other as the "reverse" indication magnet, and each signal lever is equipped with one, known as the "lock" magnet. The object of these locks, or "indications" is to insure that the movement of each signal and switch shall correspond with the movement of the lever governing it. To the shaft of each lever a segment is attached for every lock, which engages with the latches of such locks and prevents the lever from being moved from one extreme position to the other until the switch or signal has responded to the preliminary movement and through circuit controllers closed the circuit of the "indication" or "lock" magnet, thereby lifting the latch from the segment and permitting the operator to complete the stroke of the lever.

Between the mechanical locking bed on the machine, and the bracket which carries the indication magnets, is a hard rubber plate. To this plate by means of screws are fastened phosphor bronze springs. These springs extend upward and bear against bronze bands on the hard rubber roller, and when it is desired to control a signal from one or more switch levers, the springs are made to bear against the rollers of the levers, and the bands on the rollers so set with relation to the position of the lever that the circuit may be opened or closed with the lever in any position desired. These springs form what is generally known as the "Combination." Fig. 7 is a top view of a small electro-pneumatic machine, and shows the mechanical locking, the combination, and the indication and lock magnets.

At the back of each hard rubber roller, on switch levers, is a short section of hard rubber mounted loosely so as to allow the switch lever to rotate 50 degrees of its stroke without being effected, but after the switch has responded to the first movement of its lever and been locked in its new position, the segment released and the lever now free to be put to its extreme position by the operator, the last 10 degrees of its stroke acts on the loose collar and closes two pairs of contact springs which are alternately closed in one position and open in the other. These springs form part of the controller

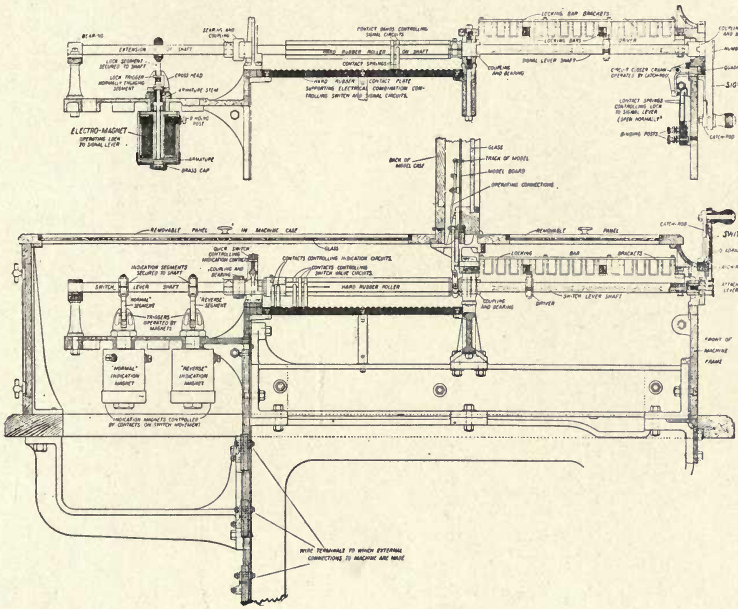


FIG. 8—SECTIONAL VIEW OF ELECTRO-PNEUMATIC INTERLOCKING MACHINE

circuit for the indication magnets. This loose piece is held from following the roller in its preliminary movement or from shifting by means of a toggle joint under the influence of a coil spring.

For the control of switches, five bands are mounted on the hard rubber roller (two of them being on the loose collar). For the control of signals two bands only are required. In addition to the regular bands on the roller, each signal lever is provided with a latch circuit controller which is normally open, and which closes a circuit on the lock magnet with the first movement of the latch, reasons for which will be explained later.

The electro-pneumatic machine is enclosed in an oak or walnut

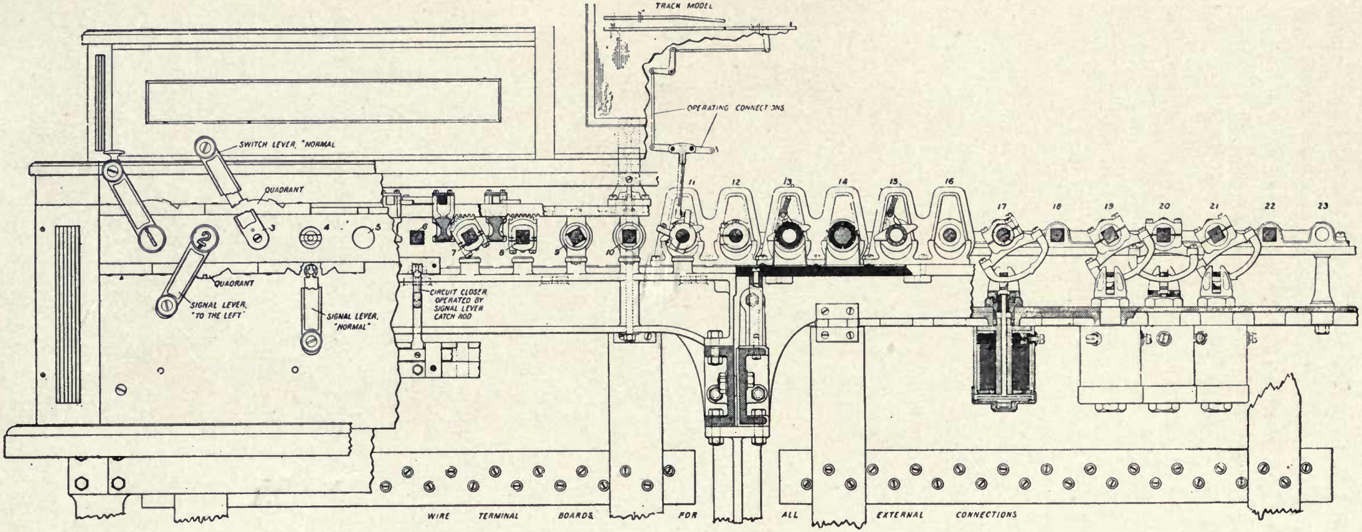


FIG. 9—SECTIONAL VIEW OF ELECTRO-PNEUMATIC INTERLOCKING MACHINE

1—Switch lever "normal" in elevation. 2—Signal lever "to the left" in elevation as used for clearing inward signals. 3—Switch lever "normal" broken to show catch rod and quadrant. 4—Signal lever "normal" broken to show catch rod, quadrant and circuit closer crank. 5—Switch lever bearing only, in front plate. 6—Section of lever shaft under mechanical rocking bed. 7—Switch lever shaft showing driver thereon engaging lock bar mounted in brackets. 8—Signal lever shaft showing driver thereon engaging lock bar mounted in brackets. 9-10—Intermediate shaft bearings under track model. 11—Section of switch shaft through coupling, and track model operating device. 12—Coupling on shaft of signal lever under track model. 13—Section through rubber roller of switch lever showing contacts of "quick switch." 14—Section through rubber roller of signal lever showing contacts of controlling signals. 15—Section through mechanism of "quick switch" in normal position. 16—Section through shaft bearing. 17—Section of switch indication magnet showing construction and arrangement of "reverse" segment. 18—Section of signal lever shaft. 19—Elevation of switch indication magnet and "reverse" segment engaging it. 20—Elevation of signal lever lock magnet and segment on shaft engaging it. 21—Elevation of switch indication magnet and "normal" indication segment. 22—Section of signal lever shaft. 23—Elevation of rear bearing.

case, the top being covered with glass, enclosed in frames, so that the mechanical locking and combination can easily be inspected. Sectional views of the electro-pneumatic machine are shown in Figs. 8 and 9.

OPERATING TOWER

This tower is usually two stories high, built of brick and of sufficient size to properly accommodate the interlocking machine, provide space for the operators, train director, telephones, telegraph instruments, etc. As previously mentioned, the machine is usually installed on the second floor, to enable the director and operators to get a good view of the tracks signalled.

In the tower, in plain view of the director and operators, are the annunciators, usually in the form of miniature signals enclosed in iron or wood cases, the blades of which are moved by rods connected directly to the armatures of vertical magnets. Working in connection with these annunciators, is a bell arranged to ring as the annunciators move from one position to the other, thereby notifying the operator of the approach of a train on the track which the annunciator indicates.

Fouling point indicators are also frequently used to indicate to the operator when a train has cleared the fouling point of a particular switch for his guidance in setting up routes for other trains. These annunciators are controlled through relays operated automatically by a section of track extending back to the fouling point.

PNEUMATIC AND ELECTRIC CONNECTIONS

The pipes for carrying the compressed air are of galvanized iron and are tested under greater pressure than they are ever called upon to stand under ordinary working conditions. The main air pipe is provided with expansion joints suitably placed, to take care of any expansion or contraction due to change in temperature. Gate valves are also installed along the line for shutting off the air at any desired place in case of a break in the pipe without the necessity of shutting down the compressors and completely "tying

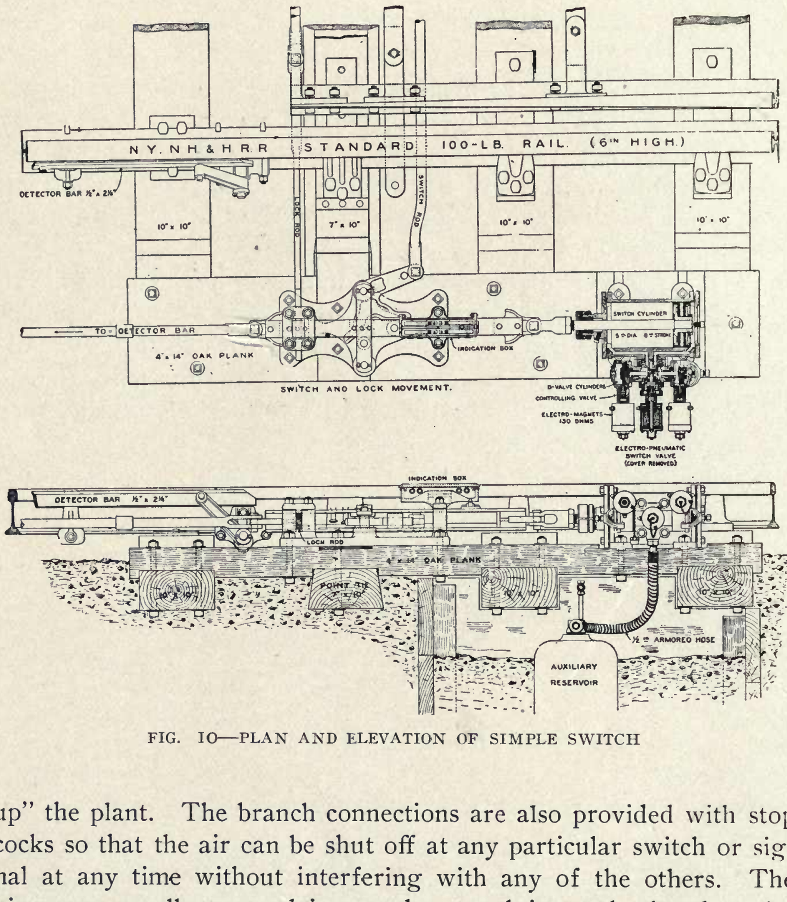


FIG. 10—PLAN AND ELEVATION OF SIMPLE SWITCH

up" the plant. The branch connections are also provided with stop cocks so that the air can be shut off at any particular switch or signal at any time without interfering with any of the others. The pipes are usually encased in wooden conduits and placed under

ground, those crossing tracks being placed deep enough to prevent any disturbance by section men when raising or lowering tracks or tamping ties.

The wires from the machine for controlling the various functions are usually carried in yellow pine conduit or "trunking" to protect them from mechanical injury. This conduit is usually supported on oak stakes or foundations about six inches above the ground, although it is sometimes buried so as to come level with the top of the ground. The former method is preferable to the latter

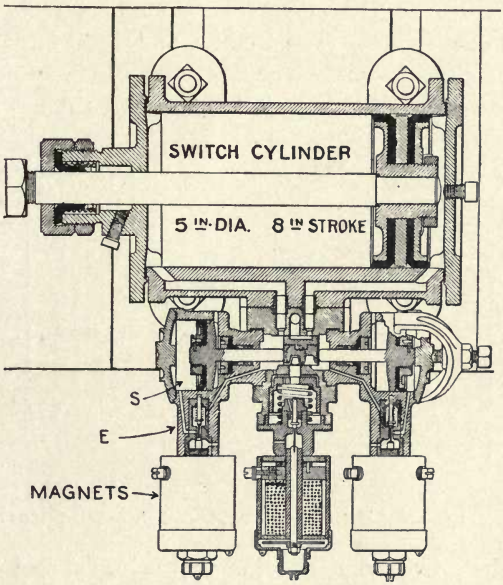


FIG. 11—SECTIONAL VIEW OF CYLINDER AND VALVE

being much easier of access and more apt to be free from moisture. The insulated wires between the machine and the various functions are usually made up in five conductor cables, as five wires are required for the control of each switch or crossover and the signals are usually so located that a cable can be used to advantage for two of them. The conductors of these cables are made of different colors so that the five conductors can be easily distinguished. A percentage of spare wires is usually provided for use in case of breaks or grounds. Terminal boxes are installed at frequent intervals

which form convenient places for conducting tests and for making joints, as no splices are allowed in the conduits.

SWITCHES—LOCKS—SIGNALS

The switches are operated by switch and lock movements actuated from air cylinders of suitable size. Both the cylinders and movements are rigidly attached to iron plates which in turn are bolted to the switch ties of the switch to be operated. Working in conjunction with each switch is a "detector" bar, the operation and function of which was described in the chapter on mechanical interlocking. Fig. 10 shows such a movement and detector applied to a single switch. The switch and lock movement has a total stroke of eight inches. The first two inches of its movement unlocks the switch and throws the detector bar, the next four inches

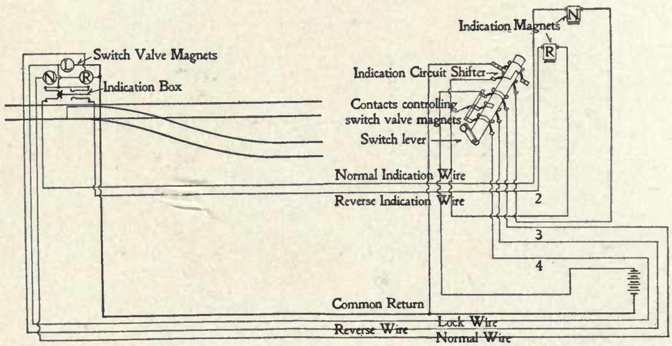


FIG. 12—CONNECTIONS FOR A SINGLE SWITCH CIRCUIT

shifts the switch from one position to the other and the last two inches locks it in its new position.

An electric switch valve which controls the admission of air to, or the discharge of air from, the cylinder is attached to each switch cylinder. In one of the chambers of the switch valve, and constantly under pressure is a slide valve mounted in a manner similar to that of a steam engine. The valve lies between the ends of two small plungers extending from the pistons of two single acting cylinders which are each provided with a separate magnet and pin valve to control their movement. The air for these pin valves is forced through a port drilled from their chamber to that of the slide valve. In practice one or the other of the pin valve magnets is energized by current from the tower at all times. Consequently the pressure is always against one or the other of the pistons used

for shifting the slide valve. A pneumatic bolt lock is applied to the slide valve and it is absolutely necessary that this be withdrawn before the valve can be operated. This bolt lock consists of a balanced piston the plunger of which is normally forced into a recess in the slide valve by the action of a coil spring. The air pressure is normally confined to the cylinder both above and below the piston, the former by a pin valve controlled by an electro-magnet. When the magnet is energized, the air is exhausted from above the piston and the pressure below it raises it, compresses the coil spring and lifts the bolt lock from the slide valve. When the magnet is again de-energized further escape of air from above the piston is prevented and the coil spring again forces the bolt lock into the slide valve. A sectional view of a cylinder and valve is shown in Fig. 11. Cylin-

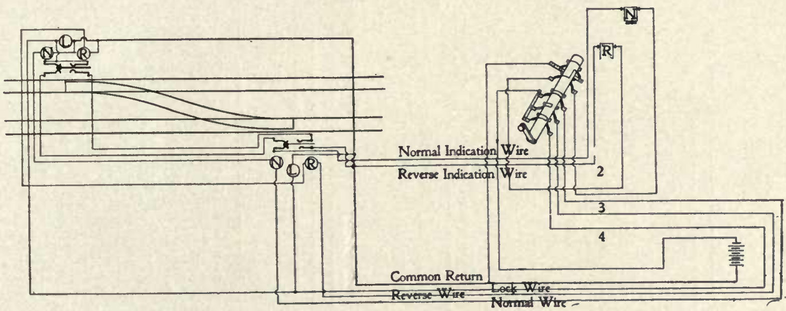


FIG. 13—CONNECTIONS FOR CROSS-OVER CIRCUIT

ders for the operation of single switches are usually five or six inches in diameter, and for the operation of slip switches and movable point frogs, seven and one-half inches. One end of a double slip and the movable frog are generally operated from the same cylinder, the cylinder being placed at the frog points, working them through two switch and lock movements coupled in tandem, and by mechanical connections working the slip points through a single switch and lock movement at the slip end. When hooked up in this manner, the switch indication box is placed on the movement farthest away from the cylinder.

In addition to the five wires mentioned previously as being required for the control of a switch, there is a common return wire for the entire interlocking. The wires are known by the function they control, viz.—a normal, a reverse and a lock control; a normal and a reverse indication. The circuits for a single switch are shown in Fig. 12. By referring to this diagram it may be seen that the first

movement of the lever in the machine energizes the centre or "lock" magnet on the switch valve before the circuit is broken on the reverse magnet, and by so doing withdraws the bolt lock from the slide valve. Continuing this movement energizes the reverse shifting magnet, and by unseating a pin valve admits the air to the reverse auxiliary cylinder, at the same time de-energizing the normal magnet and releasing the air in the normal auxiliary cylinder, thereby moving the slide valve to the opposite side by means of the piston

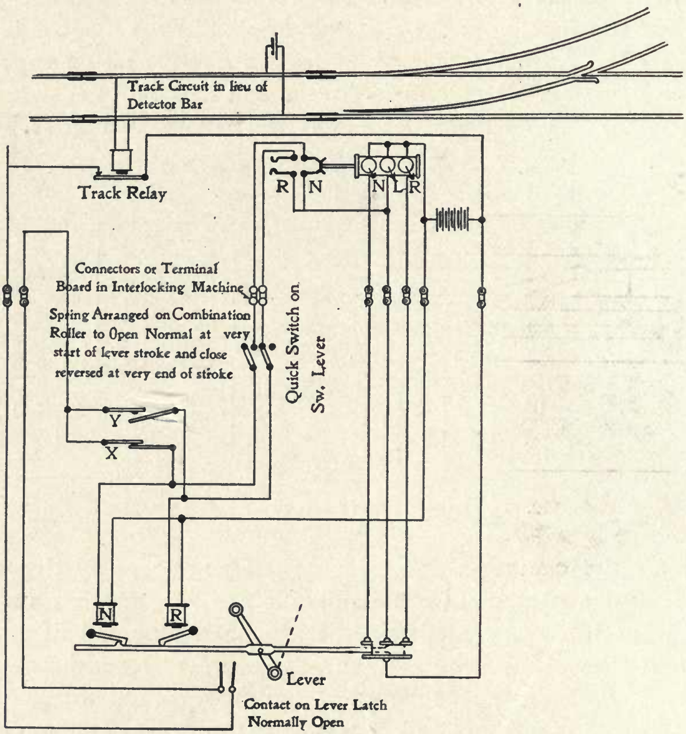


FIG. 14—CONNECTIONS FOR A SINGLE SWITCH, USING TRACK CIRCUIT IN LIEU OF DETECTOR BAR

and piston rod. The shifting of the slide valve in turn transfers the air pressure from one end of the cylinder to the other and throws the switch, through the medium of the switch and lock movement.

When a switch is normal, as shown at Fig. 12, the first movement of the lever to the reverse position breaks the normal indication magnet control on the machine and drops the armature and latch. The last movement of the switch closes the reverse indication control circuit through the indication box contact springs, showing that

the switch has been shifted and locked in its new position, lifts the armature and latch, and releases the segment which allows the lever to be placed in the extreme reverse position and the latch dropped. The placing of the lever in the extreme reverse position also releases any mechanical locking that may depend on that particular lever. The moving of a switch in the opposite direction reverses the order of these operations. When two or more switches are operated from one lever by two independent cylinders— as for example a crossover —the indication circuit is carried through indication boxes on each movement in series as shown in Fig. 13.

From the above description, it is apparent that the objections offered to the use of switch and lock movements in mechanical work, viz:—the small stroke available for locking the switch, the danger of forcing the lever completely over through lost motion in the connections, and that a switch may not correspond to the position of its lever due to broken connections, do not hold good in the electro-pneumatic interlocking system, as a positive indication must be received in the tower that the switch has make its complete stroke and has been locked, before its lever can be put to the full normal or reverse position.

FIG. 15—SIGNAL MOVEMENT AND CIRCUIT BREAKER

In many cases "electric detector" circuits are installed in lieu of the mechanical detector bars, in which case, a short section of track is insulated ahead of the switch, and the indication wire passed through a relay contact, the relay being actuated by a battery connected to the rails of the track. Where "detector circuits" are used the switch lever is equipped with a latch circuit controller similar to the one applied to signal levers, which closes a circuit on the indication magnet through the relay contact. This is illustrated in Fig. 14. From a reference to this figure it is obvious that both the normal and reverse indication magnets are normally on open circuit, and either one is energized by the first movement of the lever latch providing the "track section" is unoccupied.

High signals are of iron pipe construction. The spectacle casting carrying the semaphore arm and the colored glass for night indication are so counterweighed as to always gravitate to the "danger" or "stop" position. Hence it is only necessary to use a single stroke

cylinder to work against gravity for the operation of signals, and indicate to the operator in the tower, that the signal is in the "stop" position.

Signal cylinders are ordinarily three inches in diameter, and are fitted with an electro-magnet and valve for the controlling of the admission and discharge of air. At the side of each cylinder is clamped a circuit breaker so arranged that the circuit is made only when the signal is at "danger." A signal movement and circuit breaker are shown in Fig. 15.

As previously stated, each signal lever in the machine is equipped with a latch circuit controller, the object of which is to close a contact as soon as the latch is raised, thereby completing a circuit

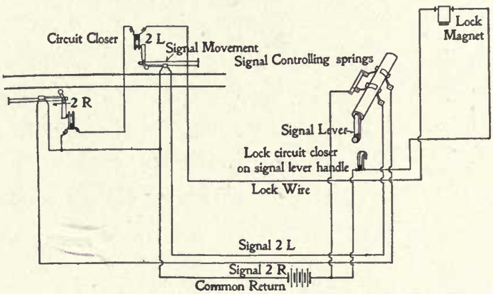


FIG. 16—DIAGRAM OF SIGNAL CIRCUITS

through the circuit controller on the signal cylinder and the lock magnet on the machine, and by so doing lift the armature and latch, release the segment and allow the lever to be moved to the right or left, depending on the mechanical locking and signal to be operated. The movement of the lever closes the circuit controlling the magnet on the signal cylinder through one of the bronze bands on the roller. The magnet in turn opens the valve and allows the air to enter the cylinder and clear the signal. A diagram of signal circuits is shown in Fig. 16. This diagram shows that when more than one signal is controlled from the same lever the lock wire is carried through circuit breakers on each of the signals so that it is absolutely necessary for all of them to be at "danger" before the lock magnet can be energized and the lever restored to its normal position.

Low or dwarf signals—used between tracks—are operated by means of direct acting cylinders, which act against strong coil springs so arranged as to be compressed when air is applied to the cylinders, in clearing the signals and to force the signals back to

"danger" when the air pressure is removed. Dwarf cylinders differ from those of high signals in that they are movable and their pistons are stationary. Their piston rods are hollow and serve as ports for the admission and discharge of air to and from the cylinder. The cylinder is directly connected to the semaphore shaft by means of a rod enclosed in the post. Fig. 17 shows a sectional view of a dwarf signal. At the side of each dwarf signal cylinder but insulated therefrom is a brass plate which closes a circuit when the signal is in the stop position by resting against contact springs fastened to

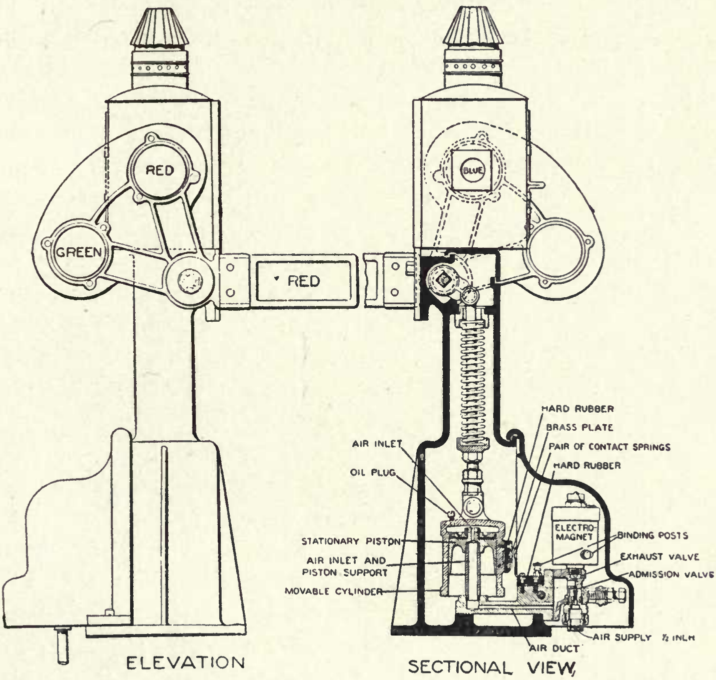


FIG. 17— DWARF SEMAPHORE SIGNAL

the base of the signal. This circuit controller performs the same functions as the one previously described in connection with the high signal.

In mechanical work, it is not considered good or safe practice to operate more than one signal from one lever although two or more can be so operated through what is known as a "selector." It is sufficient here to say that selectors in mechanical work are very unsatisfactory and unreliable. In electro-pneumatic interlocking

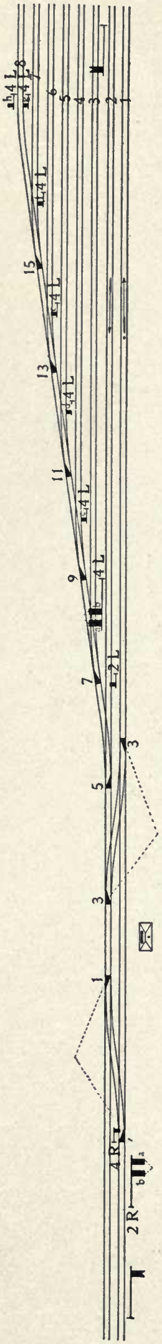


FIG. 18—LAYOUT OF TRACKS

this selection is done electrically in the tower through the "combination" on the hard rubber roller of the machine levers. Opposing signals for the same track, or signals that govern traffic up to the same track from converging tracks, may be worked with perfect safety from the same lever in the electro-pneumatic interlocking system. As a means of illustrating how this selecting is accomplished, the layout shown in Fig. 18 is assumed. Previous mention was made that the normal position of signal levers is in the central position and that they are capable of being moved to the right or left. By reference to Fig. 16 it may be seen how opposing signals for the same track are operated from a right or left hand movement of the lever. By referring to Fig. 18 it may be seen that but one train can move out of the yard to the main track at any one time and the signals governing movements to the main track are all operated from the same lever, shown as No. 4. Here is where the "combination" on the electro-pneumatic machine is used to advantage for, by it, current is supplied to the desired signal. The "combination" for the above layout is shown in Fig. 19. If, for example, it is desired to clear the signal on track 5, it is first necessary to reverse switches *5* and *11*, so that the track will be in shape for the train to proceed over it. Signal lever *4* is then moved to the left, which will energize magnet on signal *4Le*, through closed circuit breakers on levers *5*, *7*, *9*, and *11*. A study of the layout and combination will show that any one of the signals can be given through the contacts on the rollers of the switch levers.

AUXILIARY APPLIANCES

The control of annunciators is accomplished by means of a section of bonded and insulated track at the distance from the tower at which it is desired to announce an approaching train. At one

end of this insulated section is located the battery and at the other a relay. The annunciator magnet control is carried through a contact on this relay. As soon as a train strikes this bonded section the relay is shunted. This in turn opens the annunciator control and causes the miniature signal to assume the "danger position" and the

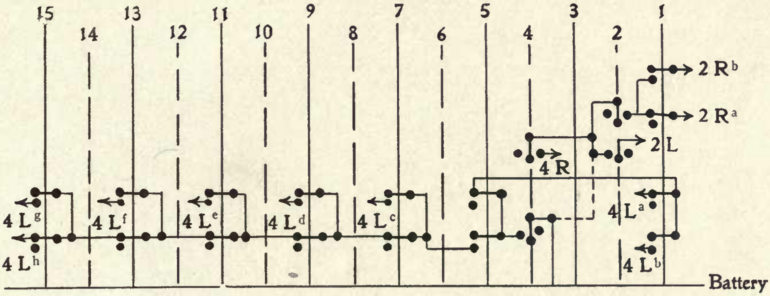


FIG. 19—"COMBINATION" FOR TRACK LAYOUT SHOWN IN FIG. 13

annunciator in so moving closes a circuit on a single stroke bell, thus indicating to the towerman that a train is approaching.

Track sections are also installed for automatically setting signals to the "danger" or "stop" position, after a train has passed them and preventing them from again being cleared as long as the train is on the track section, but this feature will be dealt with in a later article.

CHAPTER III

ELECTRIC INTERLOCKING

A VERY long stride in the direction of improved interlocking apparatus was made when electricity came into use as the motive power for operating the switches and signals. That the use of electricity for the purpose supplied a want, is proved by the rapidity with which electric interlocking has assumed a place second to none in the estimation of the railroad world. Electric interlocking was first introduced commercially in 1900. Since that time growth in the number of installations has been very rapid; the number increasing in a ratio such that the number of installations in any year exceeds that of the two preceding years combined.

The superiority of electricity as a motive power in interlocking work, as well as for a great many other purposes, is due to the facility with which it can be stored and retained for indefinite periods of time with very small loss from leakage, and to the small loss incurred in transporting it from the point where it is generated or stored, to the point where it is to be used. The conversion of electrical into mechanical energy can be effected with a high degree of efficiency the question of efficiency of conversion, being, however, of less importance in interlocking work than the high degree of insulation that is possible to attain. The circuits of an interlocking plant can easily be so well insulated that the loss on account of leakage is practically nothing, and faults in insulation can very easily be detected and removed; in fact, immediate attention is called to faults of a serious nature in electric circuits, by their interference with the proper operation of the plant.

When a switch lever in a mechanical interlocking plant is moved from normal to reverse and latched, the locking between it and the signal lever, controlling the signal governing movements over the switch reversed, is immediately released. When the lever is reversed and latched, it is assumed that the switch has followed the movement of the lever and is also reversed and locked. The possibility of the pipe line breaking, or buckling enough to allow the lever to be put into full reversed position with the switch only partly reversed, is not considered. But when electric power is used

for operating the switches (and the same may be said of other forms of power), the movement of the lever merely turns on the power and it is not safe to assume that the switch necessarily follows the movement of the lever and takes up a position corresponding. The circuit may be open at any one of a number of places so that current will not reach the motor at all; or the movement of the switch may be obstructed so that the motor is unable to move it. In order that a failure of the switch to respond to the movement of its controlling lever, may not result in dangerous consequences, the lever movement is divided into two parts: the preliminary movement for closing the operating circuit of the motor and the final movement for releasing the locking of other levers. The lever is stopped at the end of the preliminary movement by a latch known as the indication latch, because its disengagement from the lever serves as an indication that the switch

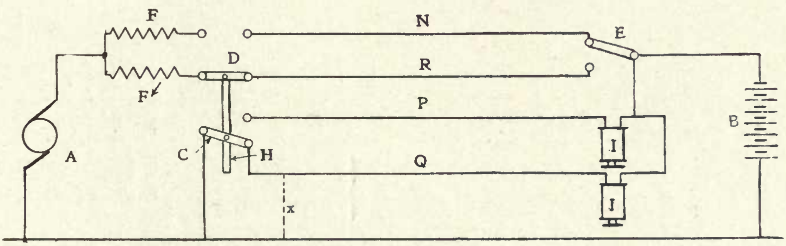


FIG. 20

has been moved home and locked. The latch is lifted and the lever freed to make its final movement at the proper time by an electromagnet or motor known as the indication magnet or the indication motor.

The necessity for an indication or automatic release of the locking when power of any kind is used for operating switches, was recognized from the first, but the problem still confronting the signal engineer was to find a suitable source of current for energizing the indication magnet. The first thought that would occur to one trying to solve the problem, would be to employ the main source of current used in operating the plant, for energizing the indication magnet, and have the switch mechanism operate a circuit controller to close the indication circuit at the proper time. Such a method is shown diagrammatically in Fig. 20, divested of most of the apparatus and circuit controllers not directly concerned in the formation of the indication circuits. An indication circuit is

closed in either extreme position of the track switch, by the circuit closer *C* actuated by the rod *H* which is connected to some point of the switch movement, preferably to the lock bar. It can easily be seen by a mere inspection of the diagram, that an accidental contact of the wire *Q* with the common return wire, such as could easily happen through faulty insulation, and as indicated by the dotted line *X*, would cause an indication to be given irrespective of the position of the controller *C* and, therefore, irrespective of the position of the track switch. An actual contact of the two wires is not required to produce this result. If both are grounded the effect is the same. No matter how good the insulation may be or how carefully the work of construction and installation may be done, there is always the possibility that the insulation may break down. An indication given by a current drawn from the main source of supply

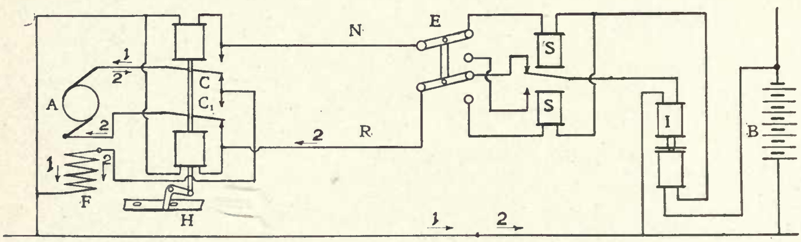


FIG. 21

which operates the plant, is, therefore, little better than no indication at all. It will be noticed that this method of operation and indication requires four wires, two operating and two indication, extending between the lever and the switch, in addition to a wire which is common to all switches lying in the same general direction from the cabin.

DEVELOPMENT OF ELECTRIC INTERLOCKING

The first real step towards developing a practical system of electric interlocking, was made when a means was discovered for utilizing a current generated by the switch operating motor itself, for actuating the indication magnet. This method is illustrated by Fig. 21 in which the parts are shown in the proper connection for generating the indication current. During the switch movement supposed to be just completed, the controller *CC'* was in the upper position when current flowed through the armature and fields in the direction of the arrow *1*, and the counter electro-motive force had

the direction indicated by the arrow *2*. At the instant the switch movement is completed, the controller *CC′* is shifted to the position shown, which puts the motor and indication magnet on a circuit independent of the battery. The electro-motive force induced in the armature, which is still rotating due to the momentum previously acquired, drives a current, through the indication magnet in the direction of arrows *2*. It is obvious that the only effect that a connection between the wire *R* and the common wire could have, would be to prevent current reaching the indication magnet; thus the error, if any, would be on the side of safety. If the wire *R* should by accident become connected to *N*, current would flow through the indication magnet, but harm from this is prevented by putting another magnet with its coils in circuit with the wire *N*, directly under the indication magnet, so that the indication armature rests normally on its poles. So long then as current is flowing in the wire *N*, the indication magnet will be unable to lift the armature, no matter how strongly it may be energized. If the wire *N* should be broken and another live wire should at the same time become connected with the wire *R*, a false indication might result; but this requires the simultaneous happening of two things, either of which alone would be immediately discovered and removed. Interlocking apparatus is considered safe when its wrong operation requires such a coincidence.

The apparatus shown at *S* is employed for removing the only remaining chance for false indication, not taken care of by the means previously mentioned. It comprises two magnets, one in each operating circuit, acting on a contact lever capable of bearing on a fixed contact on either side. The lever and contacts form a circuit switch, the function of which is to close the proper indication circuit. If the operating circuit is good so that current flows in it, the corresponding indication circuit will be closed, but then current will flow in the safety magnet under the indication magnet and will prevent a premature indication. If the operating circuit happens to be open, the corresponding indication circuit will not be closed, so that it will be impossible for a stray current to reach the indication magnet.

It will be noticed that in Fig. 21 only two wires, besides the common wire, are required for the operation and indication of the switch: the operating wire for one movement becomes the indication wire for the next movement. This system, therefore, is not only much safer than that using the main battery for indications, but requires only a little more than half as much wire.

Fig. 22 shows an entirely different method of obtaining a safe and reliable indication of the movements of the switch. In this the indication current is drawn directly from the main battery, but it is transformed into an alternating current, and an alternating-current induction motor is employed for actuating the indication latch. The transformation of the battery current into an alternating current is effected by means of a transformer and an apparatus for varying the strength of the current in its primary coil. The transformer is located in the cabin and its primary coil is included in the operating circuit. The secondary coil is connected directly to a small induction motor provided with suitable gearing to cause the rotation of the armature to lift the indication latch. The apparatus for producing the variations in the current should be located at the switch, so that the circuit closer actuated by the switch mechanism for closing the indication circuit may be between this apparatus and the transformer. A convenient means for producing the variations in the current is afforded by a collector ring on the armature shaft of the switch operating motor, connected to one segment of the commutator. At the end of the switch movement, after it has been locked, and after the motor has been disengaged from the mechanism by the clutch interposed between the motor and the mechanism for the purpose, the operating wire is switched from the operating brush to the brush bearing on the collector ring. The motor armature will continue to rotate, driven by the current entering by way of the collector ring and passing out by way of the brush connected to the common wire, and as the segment to which the ring is connected alternately approaches and then recedes from the common brush, the current in the circuit including the primary coil of the transformer will rise and fall alternately. The undulatory current thus produced, induces magnetism of a like character in the iron core, which in turn generates an alternating current in the secondary coil. The current from the secondary flows through the

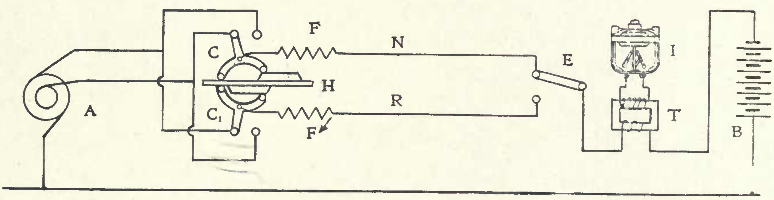


FIG. 22

coils of the induction motor causing a rapid rotation of the armature which results in lifting the indication latch.

It can easily be seen that a connection either accidental or intentional of the wire *N* with any other wire, would cause only a direct current to flow through the primary coil of the transformer, which would have no effect on the secondary except to produce a single impulse at starting of the current and again at stopping. Such impulses have only a barely perceptible effect on the armature of the induction motor, and no effect, whatever, on the "centrifuge" by means of which the rotation of the armature is converted into a direct axial thrust. As the induction motor is built to require approximately one hundred alternations per second to make it operative, it is quite apparent that it could not be affected by any succession of impulses that could be produced by accident. The accidental contact of the wire *N* with the wire to another switch which is in the act of indicating, could not result in a false indication, because it is in connection with the operating brush of the motor until the movement is completed, which would hold it at a uniform potential either high or low and would prevent fluctuation.

It will be noticed that this system, also, requires only two wires between the operating lever and the switch; the operating wire for any movement becoming the indication wire for the same movement. During the entire movement in either direction except a small part at the end of the movement, the two wires lead to the operating brush of the motor. Two field coils *F* and *F'* are provided, one in each operating wire, for the purpose of reversing the direction of the movement at any point. The field coils are so connected that currents through them from the battery produce opposite magnetizing effects, while the current always flows in the same direction through the armature. A simple means is thus afforded for reversing the direction of rotation of the motor armature, which is effected by merely changing the position of the operating lever and thus connecting one or the other operating wire to battery. The quality of reversibilty is of considerable importance, for it sometimes happens that the movement of the switch points is obstructed by something that prevents the point coming up solidly against the stock rail. If, in such an event, the switch can be put back to its original position, other routes will be freed that would be locked up if the lever had to remain in its intermediate position until the obstruction is removed. Again, the obstruction may be of such a nature that it may be crushed and might fall out of the way if the pressure of

the point were removed. A second attempt would then secure the desired movement.

Two field coils cannot be used for reversing the motor with the system shown in Fig. 21, because, as will be seen later, such means for reversal would interfere with the proper performance of the functions of another essential piece of apparatus. Reversibility is secured by attaching the cores of two solenoids to the rod connecting the blades of the controller *CC′*. By means of these solenoids, one of which is in each operating circuit, the controller *CC′* may be manipulated from the cabin.

SWITCH OPERATION BY STRAY CURRENTS

There is one other consideration quite as important as the indication, which must receive due consideration in the design of an electric interlocking system, and that is, the provision of means for preventing a stray current reaching a switch or signal motor, and

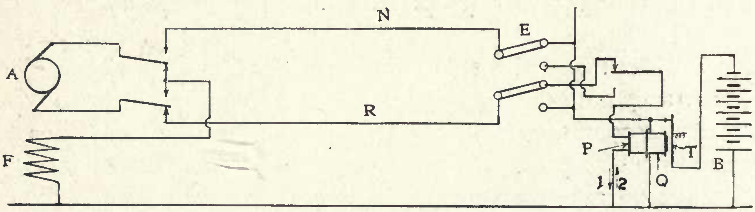


FIG. 23

causing an improper movement of the switch, or a clear indication by the signal when the track ahead may not be in proper condition for a train to pass. An improper movement of a switch, due to a stray current reaching it through faulty insulation, would have practically the same result as a false indication, as it would put the switch in a position not corresponding with the position of the lever; but, if there is any difference, the condition would be more dangerous, as there would not be as much likelihood of its being discovered by the operator.

Fig. 23 shows a very effective means for guarding against improper movements of switches and signals by stray current, as applied to the system illustrated in Fig. 21. This means comprises a circuit breaker held normally closed by current in the coils of an electro-magnet. The electro-magnet has two coils, one a high resistance coil *Q* continuously in circuit with the main battery, and the other a low resistance coil in the common lead of the indication circuits. If current flows in the coil *P* in a direction to make its

influence additive to that of *Q,* no effect is produced; but if it flows in the opposite direction, the magnet will be neutralized and the circuit breaker *T,* released, thus opening the main lead from the battery and cutting off current from the entire plant. Each indication current passes through the coil *P,* but in the direction of the arrow *2,* in which direction it aids the coil *Q* in holding the circuit breaker *T*; but a current from a live wire in contact with the wire *R* or any of its connections would flow back through the coil *P* in the direction of the arrow *1* and would cause the circuit breaker *T* to open the circuit. It can now be seen why two field coils cannot be used for reversing the switch operating motor, for the use of such coils for the purpose would cause the indication current to flow in the direction of the arrow *1,* and would open the circuit breaker *T* at each movement of a switch. It can easily be seen

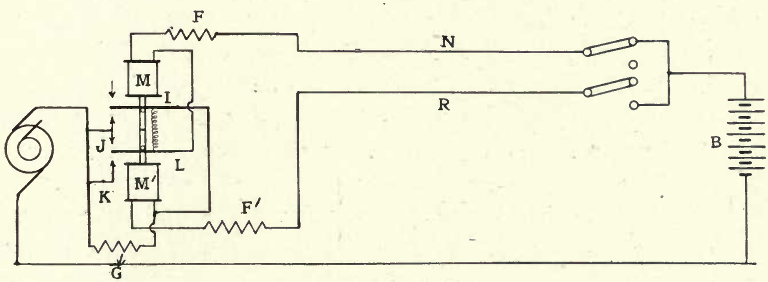


FIG 24

that the effectiveness of the device as a protection depends on the wire *R* being unbroken from the point of improper contact, back through the coil *P,* to common. But this wire was used as indication wire in making the last movement and if it had been broken then the break would have been discovered and repaired. A failure, therefore, requires, practically, the simultaneous happening of two things either of which alone would be discovered and repaired on the first attempt to operate the switch. All apparatus used in connection with the operation and indication of the switch and not directly concerned in the operation of the safety device, has been omitted from the diagram.

Another form of safety device adapted especially to the system shown in Fig. 22, is illustrated in Fig. 24. This apparatus is located near the switch motor and comprises two solenoids for operating circuit controllers. Only enough of the circuits are shown to illustrate the principles of its action in preventing improper movements.

The instrument also serves to open the circuit and stop the current when the lever movement is completed, and to switch the indication wire from the brush bearing on the collector ring, to the operating brush preparatory to the next movement. The wire *R* is the one that will be used to lead current to the motor for effecting the next movement of the switch. The preliminary circuit includes the field *F′*, magnet *M′*, lever *L′*, and resistance *G′*. Current in this circuit will energize the magnet *M′*, causing it to attract the lever *L* which it will pull up against the contact *K*. If the current is properly started by a movement of the controlling lever in the cabin, the lever *L′* will also be drawn back against the contact *J*, thus cutting the resistance *G′* out of the motor circuit; but if the current enters the wire *R* through faulty insulation the lever in the cabin not having been moved, a current will flow in the circuit including the field *F*, magnet *M*, lever *L*, and the armature, and will result in holding the lever *L′* away from the contact *J*. The latter circuit has no extra resistance in it, while the former includes the resistance *G*. The current through the field *F* will, therefore, be very much stronger than that through *F′*, and it will determine the polarity of the field magnet, which will be the same as it was in making the last movement. The motor armature will, therefore, rotate idly in the direction it did in making the last movement, and without any effect on the switch mechanism. It may be well to mention here that the motor armature is connected to the mechanism by means of a clutch which permits the motor to be disengaged at the end of each movement, and to run without load while transforming the current for indication. It also runs without load when the safety device becomes operative to prevent an improper movement. The counter electro-motive force of the motor acts as a resistance to limit the current required to operate the safety device to three or four amperes. The circuits, both that improperly charged and the safety circuit, lead to the same brush of the motor. The former includes the resistance *G′* which, with the maximum resistance in the lines, reduces the current in the field *F′* to one-fifth that in the field *F*.

It will be noticed that, in this method as in that previously described, the action of the safety device depends on the continuity of a wire. In this case it is the wire which was last used in operating the switch and which must have been good when the last movement was made. The two methods are, therefore, equal in the degree of safety afforded. There is one point of difference that may

be worth mentioning. The safety device shown in Fig. 24, when it becomes operative, affects only the switch to which it is connected, while that shown in Fig. 23 throws the whole plant out of service, or as much of it as is connected to one common return. If the circuit breaker *T* is cut into the common instead of the main positive lead, and one cut-out is provided for each common return, then when one of them is opened by an improper connection, only that part of the plant served by that common return is put out of service. Obviously, this principle could be extended, so as to cut out only one switch, by using a separate return for each switch instead of a common wire, and by putting a cut-out in each return.

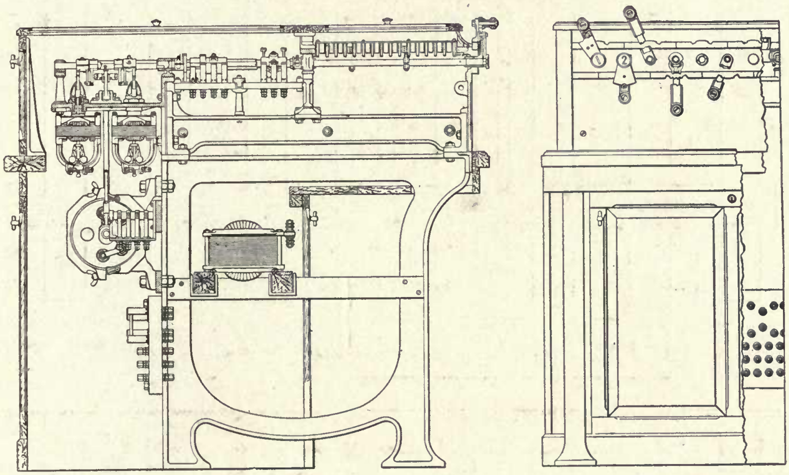


FIG. 25—VIEWS OF ELECTRIC INTERLOCKING MACHINE SHOWING END AND FRONT ELEVATION

After what has been written in preceding articles descriptive of interlocking apparatus, an extended description of the apparatus used in connection with the all-electric system is unnecessary. A brief description of the more important parts peculiar to the electric system may, however, be of interest.

An interlocking machine now in quite extensive use, is shown in Fig. 25. This resembles, in general appearance, the electro-pneumatic machine already described. The only difference is in the indication apparatus which, for the electric machine, is adapted to the alternating current described in connection with Fig. 22. The indication motor has its armature shaft in a vertical position, to which is

attached a piece of centrifugal apparatus very similar in construction to the well known form of governor used on the steam engine. The rapid rotation of the armature causes the weights to separate, and through a system of levers, to lift the indication latch and release the lever. This mode of construction makes it necessary to have a very rapid rotation of the indication motor armature to produce the desired effect, and this rotation can be secured only by a rapid succession of alternating impulses in the coils of the motor. A direct current through these coils has no effect other than to lock the armature against rotation.

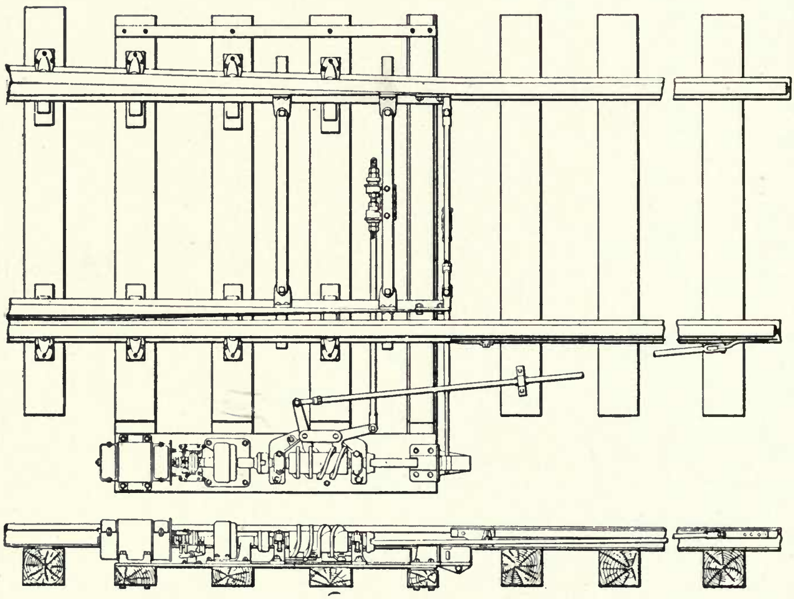


FIG. 26 AND 27—PLAN AND ELEVATION SHOWING ELECTRIC SWITCH AND LOCK MOVEMENT

SWITCH AND LOCK MECHANISM

Fig. 26 is a plan and Fig. 27 a side elevation, showing a switch and its operating mechanism. The switch and lock movement is driven by a direct-current motor of about 1.5 hp, designed to be operated at 110 volts. The shaft of this motor is connected by means of a magnetic clutch to a shaft extension in the same line, working a cam drum, which operates the switch and lock. Intermediate between the magnetic clutch and drum, there is a reduction gearing

with a speed ratio of twenty-five to one. It will be noticed that there are two cams on the drum, one of these working the lock rod and detector bar, and the other the switch, connection being made to the detector bar and switch through cranks. The lock is worked direct by a straight bar which slides longitudinally underneath the cam, motion being imparted by means of a lug fitting the cam slot. It will be noticed that in each case the cam slot, for a portion of its travel, moves in a plane at right angles to the shaft, so that while that portion is passing the hub on the driving bar or crank, no movement of the latter takes place; it is only while the hub is engaged by the diagonal portion of this slot, that movement is imparted to the switch or lock mechanisms. The operation is therefore on the principle of the switch and lock movement, with which signal engineers are quite familiar, and briefly is as follows: When the drum is revolved by the motor, the lock rod and detector bar immediately begin to move, and as soon as these have completed their stroke, the motions of these mechanisms cease and the movement of the switch begins. After the switch has been moved over against the stock rail, further motion of the lock bar locks the switch and at the same time operates a knife switch which opens the control circuits and closes the indication circuit.

A noticeable feature of this switch and lock movement is the arrangement of the parts in one long and narrow mechanism which occupies but little space between the tracks. For this reason it can be used in many places between tracks that come too close together to admit movements of other design, which in some places must be placed outside the tracks with long rod connections, passing under intermediate tracks to the switch. Another feature of this design worth noticing, is the fact that the cam drum is reversible, so that the movement can be operated either right or left, merely by changing the drum end for end, the position of the motor and clutch remaining the same. The motor, clutch, and drum are all attached to a steel base plate.

Returning now to the motor part of the movement; the direction of rotation for reversing the switch is controlled by means of a double field winding, one part of which is cut out while the other is in circuit. When the switch is to be thrown in the reverse direction, the lever on the interlocking machine merely changes the connection of the operating circuit to the other field winding.

The use of the magnetic clutch is an advantage in several ways. It permits the breaking of the motor connection with the throwing

mechanism instantly and at the proper time, and the absence of a rigid connection prevents breaking or straining of the parts if the movement of the switch should become blocked, as by the dropping of a lump of coal or other obstruction. The blocking of the switch

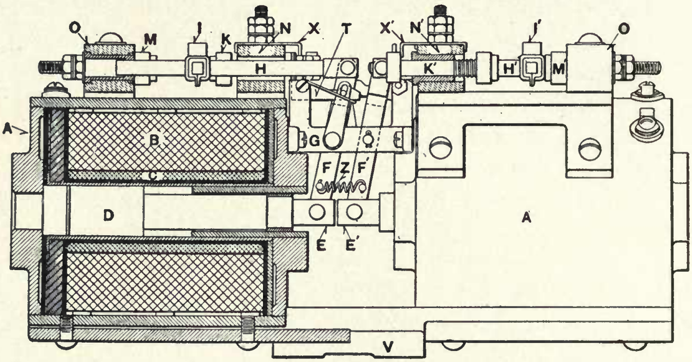


FIG. 28—SIDE ELEVATION OF SOLENOID SAFETY CIRCUIT CONTROLLER FOR SWITCH MOVEMENT

merely causes the clutch to slip until a fuse is blown on the interlocking machine. It should here be noted that the motion of the switch follows the lever. If the switch is found to be blocked, it can be thrown back by simply reversing the lever.

SAFETY CONTROLLER FOR SWITCHES

The safety controller used with the system shown in Fig. 24, and which automatically cuts out a switch motor if the lines be-

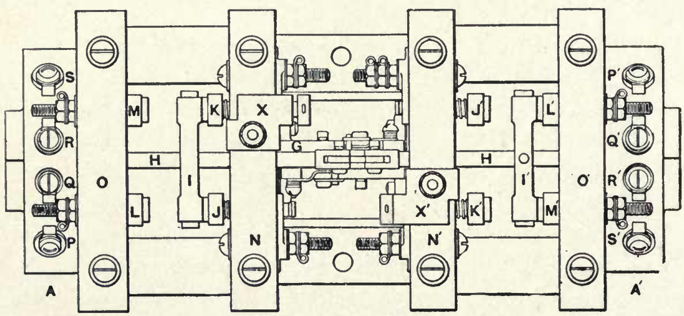


FIG. 29—PLAN VIEW OF CIRCUIT CONTROLLER

come improperly connected, combines in one, the functions of two electro-magnetic circuit controllers. The function of one is to open the motor circuit when the lever movement is completed, and of the other to open the next operating circuit when it is energized by con-

nected wires, and thus to prevent a wrong movement. The instrument which is illustrated in Figs. 28, 29, 30 and 31 comprises two solenoids *A* and *A,* fixed to a cast iron base *V.* Each solenoid has a moveable core *D,* connected by means of a jaw *E* to a lever *F.* The lever *F* is pivoted at its middle to a fixed support *G* and is connected at its upper end to a rod *H,* free to move longitudinally. The rod *H* carries a contact bridge *I,* which will connect the contact points *J* and *K* when the core *D* is drawn into the solenoid, and will connect the contact points *L* and *M* when the core *D* is drawn outward. The levers *F* and *F′* are connected near the lower ends by a spring *Z,* which causes the bridge *I′* to connect *L′* and *M′,* when the core *D* is drawn into its solenoid *A* to nearly the full extent. Similarly the contact bridge *I* is made to connect *L* and *M* when the core *D′* is drawn into the solenoid *A′.* The contacts *J* and *K* are carried by the slate block *N,* with springs interposed so that they may be pushed in about three-sixteenths of an inch. The contacts *L* and *M* are fixed to the slate block *O.* The relation of the parts is such, that the bridge *I* touches the contacts *J* and *K,*

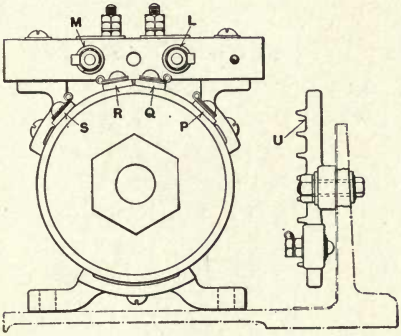


FIG. 30—END ELEVATION OF CIRCUIT CONTROLLER

while the core *D* is still three-sixteenths of an inch from its complete forward stroke, and the bridge *I′* touches *L′* and *M′* with the core D about one-sixteenth of an inch from its full inward stroke. These clearances are allowed for making good contact. Each solenoid has two coils of wire. The coil *C* has 100 turns of No. 13 B. & S. gauge and the coil *B,* 1 100 turns of No. 15 B. & S. gauge. The resistance coils *U* and *U′*, each of twenty ohms, are in series with the coils *B* and *B′* at the starting of a movement, and the circuits including them may be called the starting circuits. The coil *B* is connected to terminals *P* and *Q,* and the coil *C* is connected to terminals *R* and *S.*

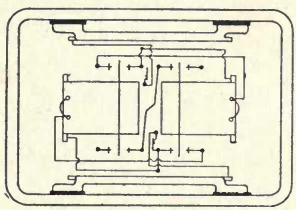


FIG. 31—WIRING DIAGRAM

At the beginning of a movement, current flows through coils *C*, *B*, and *U* in series, and draws in the core *D*, causing the bridge *I′* to connect *L′* and *M′*, which shunts the coils *B* and *U*, so that the operating and indicating currents flow only through the coil *C*, of a very low resistance, but having sufficient turns to hold the core *D* in place. The bridge *I* will touch *J* and *K* before *I′* touches *L′* and *M′*, so that if the current happened to come from a foreign source without the lever having been moved, current would also flow from the last operating wire, which is still in connection with battery, through coils *C′*, *B′*, bridge *I*, and the motor, and would hold *I′* away from *L′* and *M′*, by drawing in the core *D′*. This current will run the motor light in the direction it ran in making the last movement, and without energizing the clutch. The contact *K* is provided with a head on its inner end, which makes connection with a contact *X*, when *K* is pushed outward by the spring, but when *K* is pushed in by the bridge *I*, it is separated from *X*. The object of this is to cause the cut-off current to flow only through the safety contacts *J* and *K*, and thus afford a test of their condition at each movement of the switch.

When the core *D* is drawn completely into the solenoid *A*, the latch *T* drops into the path of a projection on the lever *F′*, so that if the magnet *A′* is energized while *A* is still holding its core, the core *D′* will be stopped by the latch *T* before it puts the bridge *I′* against *J′* and *K′*. A similar latch, *T′*, stops the core *D* under similar conditions. These latches come into play in the action of the cut-off current. If in that case the bridge *I′* were allowed to move far enough to touch *J′* and *K′*, the safety circuit would be temporarily closed and cause sparking at the contacts.

CHAPTER IV

THE ELECTRIC TRAIN STAFF SYSTEM

DEVELOPMENT

THE electric train staff system of to-day is a gradual development from a simple principle for the operation of railroads which was recognized in England as early as 1840; namely, that to safely pass over a given section of single track, every train should have in its possession a tangible right to do so in the form of some specific article of which there is only one obtainable. The first train staff was a metal bar about two feet long, which had cast or engraved on it the name of the two stations between which it alone gave authority for any train to proceed. Unless trains moved alternately in opposite directions the staff had to be returned over the section by a special engine or in some cases by road.

To partially overcome this difficulty the staff and ticket system was devised, in which device the original staff became a key that would unlock a box at either end of the section and permit tickets to be taken therefrom. If it was desired to forward, say three trains from one station to another before one should proceed in the opposite direction, the ticket box was unlocked by the staff and a ticket given to the first and second trains, the third train receiving the staff.

Since an engineer or guard of any train when receiving a ticket was required to see the staff as well, this system, while making head-on collisions impossible, did not permit trains to enter a section from the end at which the staff did not happen to be. To accomplish this result, Mr. Edward Tyer, in 1878, introduced his electric tablet apparatus, which consisted of two instruments, one at either end of a section, each instrument containing a certain number of tablets any one of which constituted the right of a train to pass over that section. The two instruments were electrically connected and synchronized so that the removal of a tablet from either instrument absolutely prevented any other being taken out.

In 1889 Mr. Webb, the chief mechanical engineer, and Mr. Thompson, the signal superintendent of the London & Northwestern Railway, invented the Webb & Thompson electric train staff, in which staffs were substituted for the tablets in the Tyer system and a permissive feature added whereby several trains could follow each

other into a block section if desired, in a manner similar to that employed in the non-electric staff and ticket system.

The first installation of the Webb & Thompson system was made with eminently satisfactory results in May, 1894, on the Chicago, Milwaukee and St. Paul Railway between Savanna, Ill., and Sabula, Iowa, and is described herewith:

APPLICATION OF TRAIN STAFF SYSTEM *

"The lines of the Southern district of the Chicago, Milwaukee & St. Paul Railway cross the Mississippi river between Savanna, Illinois, and Sabula, Iowa. The distance between these two stations is three miles, and there is one grade crossing, one draw bridge, and one local station in the block. Over this track, which is single, the traffic of about three thousand miles of the St. Paul company's lines passes. These lines extend directly to Kansas City, Omaha, Sioux City and Chamberlain on the west, and to Chicago, Milwaukee and Racine on the east. During the larger part of the year the traffic is heavy (the bridge block being the neck of the bottle, so to speak) and rarely falls below fifty trains per day at any time.

The division yard is located at Savanna, on the east side of the Mississippi river, making it necessary for the trains of both divisions west of the river to use the bridge block, and, moving the traffic from so large a territory, it is to be expected that they will be irregular in number, and that they will bunch during certain hours. The use of a time table showing the trains over the river block was abandoned, because it was found impossible to arrange it so that it was a reasonably correct exhibit of the traffic. Nor was it possible to move the trains through the dispatchers of either division, as the work on their respective divisions would not permit the close attention to the bridge block which the nature of the service demanded. For a time in the early history of the bridge this was done, but the work was finally put in the hands of the operators at each end of the block. It was found to be necessary to use some other than the ordinary dispatching systems. That was found to be too slow and cumbersome to meet the requirements of the quick work necessary under the conditions constantly arising incident to unexpected delays, and to increase or decrease of traffic. To meet the conditions described a train order by card system was adopted, which was in successful use for

*From a paper read before the Western Railway Club by Mr. C. A. Goodwin, at that time superintendent of the Chicago, Milwaukee & St. Paul Railway.

many years. It was virtually a staff system—the card representing the staff—but it lacked one element: it was impossible to interlock the cards. As traffic increased, and increased acceleration of trains became necessary, it was apparent that the company would be compelled to either double-track the bridge block or find some unobjectionable way of handling the trains. Owing to the character of the country the construction of a second track would have been very expensive, and the selection of a satisfactory system for handling the traffic became the subject of much thought and investigation. After a thorough examination and inquiry the Webb-Thompson electric staff system, largely in use on the London & North-Western Railway and in Australia, was adopted and placed in service in May, 1894. This was the first installation of the staff system in the United States, and probably in either of the Americas.

"From the preceding brief description it is clear that with this system the bridge dispatcher has no responsibility except to give the proper trains the preference. He may delay traffic, but he cannot create a condition of danger. It is not necessary for him to provide for a proposed or supposed movement of trains by sending numerous orders, only to find it necessary to cancel them because the train cannot move as expected. He is in touch with the yardmaster at Savanna and with the dispatcher at both divisions, and through these sources is fully informed in regard to the probable movement of trains in both directions. He may have expected to hold a freight train for a passenger train, which is reported on time at some distant station, only to find that the passenger train has lost time and that he can just squeeze the freight train into the terminus. There is no necessity for sending hurried orders with attendant possibility of errors. He simply signals for a staff, and in five seconds or less the engineer has his authority to go forward. Or supposing the situation reversed. A passenger reported late has made up so much time that another train which is approaching, and for which a staff has been withdrawn, cannot go forward. Transportation men know the delay which results when it is necessary to change or make void telegraphic orders. No such delays occur with the staff system. It is only necessary to leave the signal at danger, replace his staff in the instrument (enabling one to be withdrawn at the other end of the block,) and the passenger train goes forward with no loss of time. In case of there being so great a delay to a train, to which a staff has been delivered, that it is desired to recall its permission to move, the staff is brought back to the office and replaced in the instrument,

thereby cancelling its authority to proceed and in a manner which cannot be misunderstood.

"When a work train is to occupy the block the delivery of a staff means that it is to be protected in both directions, and that no flagman need be sent out, delaying fifty or a hundred men while he comes in.

"These few examples of the many complications that must necessarily arise in the handling of traffic on a single track are cited to illustrate the facility with which the staff system does its train dispatching; its possibilities in connection with the movement of trains on single track, and its especial adaptability to short stretches of track used by the trains of several divisions or different railways, as compared with the telegraphic movement; the advantage both as regards safety and facility of handling being distinctly with the staff system.

"It is not the intention to decry our system of train dispatching. There can be no question but what it is a most economical and satisfactory method of handling traffic under ordinary conditions with not too heavy a train movement; but we are obliged to admit that the system is open to objections which particularly relate to safety as well as facility. The staff system is capable of extended application. It is at once a block signal, a train dispatcher and a time table. It is to the movement of trains between stations what the interlocking of switches and signals is at stations and grade crossings."

The main objection to the extended adoption of the Webb & Thompson apparatus was the size of the staff, which made it difficult to catch at high speed. To overcome this objection, a new design was introduced in 1900, known as the high speed train staff system, which was based on the same general principles and method of operation as the Webb & Thompson, but possessed the essential advantage of employing staffs only six inches in length, weighing six and one-half ounces; as against staffs twenty-two inches long, weighing four pounds, of the Webb & Thompson system, thus greatly simplifying the problem of taking the staff at high speeds.

On the Atchison, Topeka & Santa Fe Railway, among other places, it was applied to a section extending from Trinidad, Colorado, to Raton, New Mexico, a distance of 25 miles, which was divided into seven block sections. This portion of the Atchison comprises mountain grades averaging three and one-half percent for a greater part of the distance, over which a traffic of approximately 60 trains a day is operated. On account of the number of trains, and also from the fact that each train required two and sometimes

three engines on the up-grade, an average of one hundred and fifty train orders was issued in each twenty-four hours, most of which were sent to not less than two stations, so that the total delay to trains awaiting these orders can easily be imagined. With the introduction of the staff system as many, or more, trains have since been handled over this section with no collision and a minimum of delays. At the intermediate stations on this section, staff cranes are provided from which the enginemen can take the staffs at a speed up to 25 miles an hour without the use of any special attachments on the engine.

The latest type of staff instrument, known as the electric high-speed train staff, Model No. 2, has been developed during the past four years, and employs practically the same size and weight of staff as the Model No. 1 machine, over which it possesses the following advantages: By having separate drums for putting in and taking out the staffs, equal wear on all staffs is secured; whereas, in the earlier instrument some of the staffs would be practically worn out from constant use, while others were hardly ever used at all. The second advantage lies in the special type of indicator employed in this machine, which plainly shows the operator by the display of a white or red disc whether or not his instrument is in condition for him to remove a staff, and thus leaves him no excuse for unduly forcing the mechanism. Numerous other improvements exist in this type of machine, but they consist principally in minor details of construction.

An installation of this type has been in operation over fifteen months on a section of the Southern Pacific Railway between Truckee, California, and Colfax, California, a distance of 98 miles, divided into 37 blocks. This portion of the Southern Pacific is in the Sierra Nevada mountains and 14 of the staff stations are located in the snow sheds, of which there are nearly 40 miles.

PRINCIPAL ADVANTAGES OF THE ELECTRIC TRAIN STAFF SYSTEM

While in the foregoing the general principles on which the electric train staff is operated have been described, yet particular attention is called to the following points:

First—The electric train staff system may be considered as a mechanical assistant, which issues metal train orders under the general direction of the train despatcher, giving trains the right to proceed over certain sections of track, and will only issue one such order at one time for any section, except in the case of following

trains where the permissive feature is used, thus obviating all danger of "lap orders."

Second—In place of eliminating the train despatcher, as has at times been erroneously supposed, the train staff, by removing all dangers of collision and doing away with all train orders, relieves his mind from the constant strain imposed upon it under the present system and thus gives him ample time to issue orders to operators on his division for the proper movements of the trains under his control.

Third—It avoids all the delay now experienced in waiting for train orders. If conditions are right for a train to proceed the staff can be obtained immediately and when the permissive system is employed trains can follow each other as closely as the rules of the road permit.

Fourth—It alone of all block systems provides a tangible piece of evidence in the shape of the staff to the engineer or conductor of his right to the particular block section he may occupy.

Fifth—It can be surrounded with all such additional safeguards as conditions and locations may warrant, including semaphore signals and continuous track circuit, electric locks, etc.

Sixth—It can be safely operated by any railroad employee of average intelligence. A knowledge of telegraphy is not necessary for its operation.

Seventh—At stations where telegraph operators are employed who have other duties, it is found that the operation of the staff takes up considerably less of their time than is now expended on telegraphic train orders.

Eighth—In most installations, the absolute staff system is employed which permits but one staff to be out of any pair of machines at one time and consequently allows but one train in a block.

In a number of cases, however, where the blocks are of necessity long and traffic is heavy through certain portions of the day, the permissive feature is introduced which, while it makes it impossible for two trains proceeding in opposite directions to be in any given block at one time, permits as high as twelve trains to follow each other in the same block at close intervals.

ABSOLUTE STAFFS AND STAFF INSTRUMENTS

In the operation of the electric train staff the track to be protected is divided into blocks or sections of such length as to best accommodate local and traffic conditions. These blocks usually terminate at existing stations or telegraph offices, though occasionally, as in the telegraph block system, additional block stations have to be installed when the distance betwen any two existing stations is too great for the expeditious handling of traffic.

Each section is controlled by two instruments of the type shown in Fig. 32, one at each end of the section, which for convenience in this description are referred to as "*X*" and "*Y*." Each instrument is equipped with a sufficient number of staffs (varying from 10 to 35 per section) to take care of the traffic conditions. No train is permited to proceed between *X* and *Y* in either direction unless the conductor or engineer has in his possession one of these staffs which is in effect a metal train order. The instruments at *X* and *Y* are electrically connected and synchronized so that the withdrawal of a staff from either can only be effected by the joint action of the operators at *X* and *Y*, and but one staff can be out of both instruments at any one time.

To move a train from *X* to *Y* the manipulation of the instruments is as follows: The operator at *X* presses bell key *A*, Figs. 32 and 34 the number of times prescribed in the bell code, which rings bell L, Figs. 33-4 at *Y* through circuit *1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18*. The operator at *Y* first acknowledges receipt on his bell key by ringing bell *L* (Figs. 33-4) at *X* (through circuit *19, 20, 21, 8, 7, 6, 5, 4, 22, 23, 24, 25, 17, 16, 15, 14, 13, 26*,) and then holds it closed, thereby deflecting the "current indicating needle" *F* at *X* (Figs. 32-34) to the right. This informs *X* that *Y* has furnished *X* current and he proceeds to remove the staff by turning the preliminary handle *B* Fig. 32 to the right as far as it will go, which raises the armature *J* Fig. 33 up to the magnets K (Fig. 33) transferring the current from the bell L to the coil *K88* (Fig. 34) through the circuit *19, 20, 21, 8, 7, 6, 5, 4, 22, 23, 27, 28, 25, 17, 16, 15, 14, 13, 26,* and at the same time closing the circuit on coil *K 360* (Fig. 34)

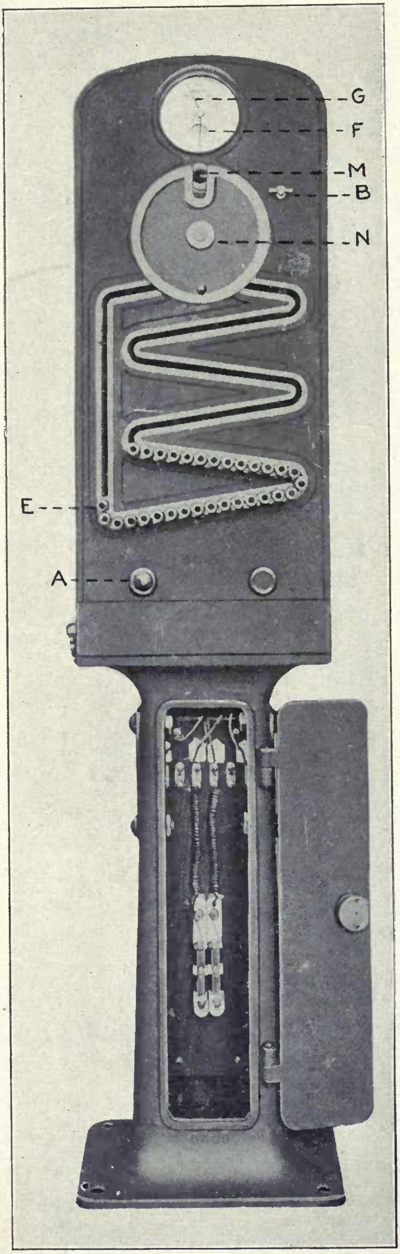


FIG. 32—STAFF INSTRUMENT SHOWING TRAIN STAFFS, REVOLVING PLATE, INDICATING DIAL, SIGNALING BUTTON, ETC.

through the circuit *1, 2, 29, 30, 28, 25, 18*, after which the preliminary spindle handle *B* (Fig. 32) is permitted to automatically return to its normal position. This unlocks the revolving drum *C* (Figs. 33 and 35) and indicates the fact by displaying a white instead of a red disc in the indicator at *F* (Fig. 32). The operator now moves the end staff *E* (Fig. 32) up the vertical slot into engagement with the drum *C*, (Figs. 33 and 35) the outer guard *N* (Fig. 32) having first been turned to the right position; revolves the latter through half a turn, using the staff as a handle, and finally withdraws the staff through the opening at *M* (Fig. 32). In making the half turn, the drum *C* has reversed the polarity of the operating current, thereby throwing the instruments at *X* and *Y* out of synchronism with each other, and moving the "staff indicating needle" *G* at *X* (Fig. 35) from "Staff In" to "Staff Out." Immediately on withdrawing the staff the operator at *X* once more presses his bell key *A*, which indicates to the operator at *Y* by moving his needle from "Staff In" to "Staff Out" that the operation is completed. A side view of a staff instrument with the outer case removed is shown in Fig. 36.

The staff withdrawn is now delivered to the train by hand if

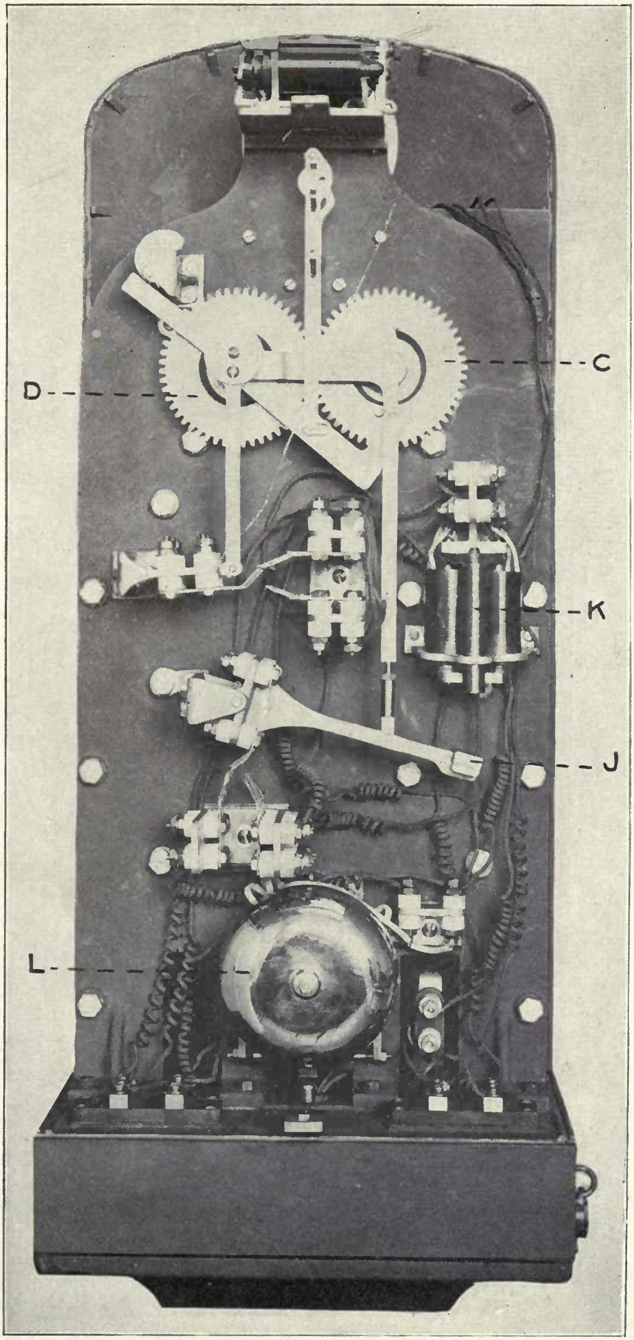


FIG. 33—BACK VIEW OF STAFF INSTRUMENT SHOWING MECHANISM

the train is at rest or passing at a speed less than 25 miles per hour. For higher speeds the staff is placed in a special holder and delivered by methods similar to those followed in the railway mail service, the engine being fitted with a catcher and deliverer. A glance at the accompanying cuts (Figs. 37 and 38) will make this clear. As mentioned before, in taking out a staff, the polarity of the operating current is reversed. This prevents a second staff from being taken out of either instrument, as may be noted from the following.

The polarity of the local current flowing through magnet *K 360* (Fig. 34) is never changed, the polarity of the current flowing

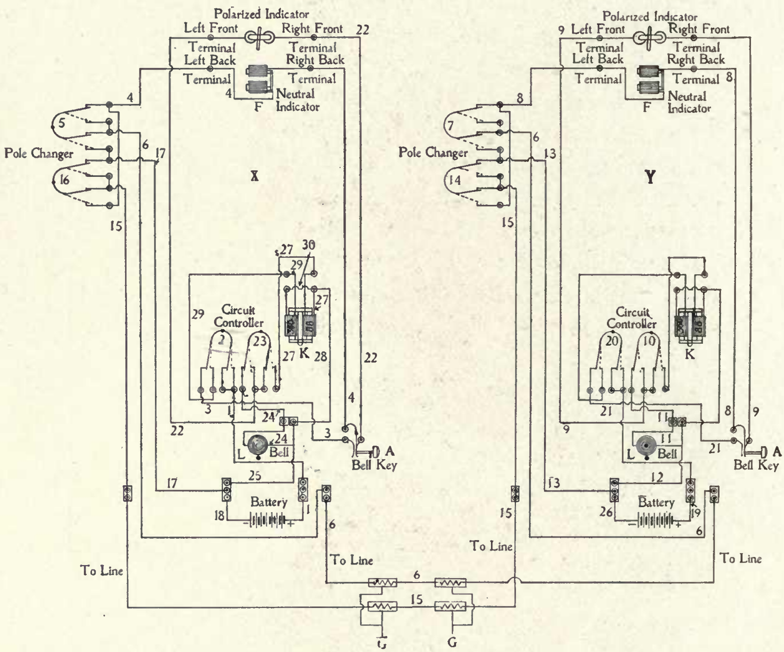


FIG. 34—DIAGRAM OF CONNECTIONS FOR SIGNALING, INDICATING AND OPERATING CIRCUITS FOR ONE BLOCK SECTION

through *K 88* (Fig. 34) is changed each time a staff is put in or taken out of either instrument. This puts the instruments either in or out of synchrony. The magnet *K* (Fig. 34) is formed of two separate coils, one energized by the local and one by the line battery. The construction of this magnet is such that when the currents in both coils run in the same direction, the lines of force flow around the cores and connecting straps, thus forming no point of attraction for the armature. When the current is reversed in one coil, however,

the lines of force oppose each other and the armature being brought to the point of attraction is held there. With the staff out, the circuits are as follows:—starting from the + side of battery at Y, (Fig. 34), through *19, 20, 21,* Bell Key A closed, *8, 7, 6, 5, 17, 25, 24, 23, 22, 4, 16, 15, 14, 13, 26,* to—side of battery at *Y*. If an attempt be made to release a staff by turning the preliminary handle, the operating current would be transferred from the bell *L* to coil *K 88* (Fig. 34) through *19, 20, 21,* bell key *A* (at *Y*) closed, *8, 7, 6, 5, 17, 25, 28, 27, 23, 22, 4, 16, 15, 14, 13, 26* to—side of battery at *Y*. By comparing this circuit with the one described for releasing a staff, it will be seen that in the former the currents flowing through coils *K 360* and *88* (Fig. 34) oppose each other and in the latter they do not, which prevents the releasing of a staff.

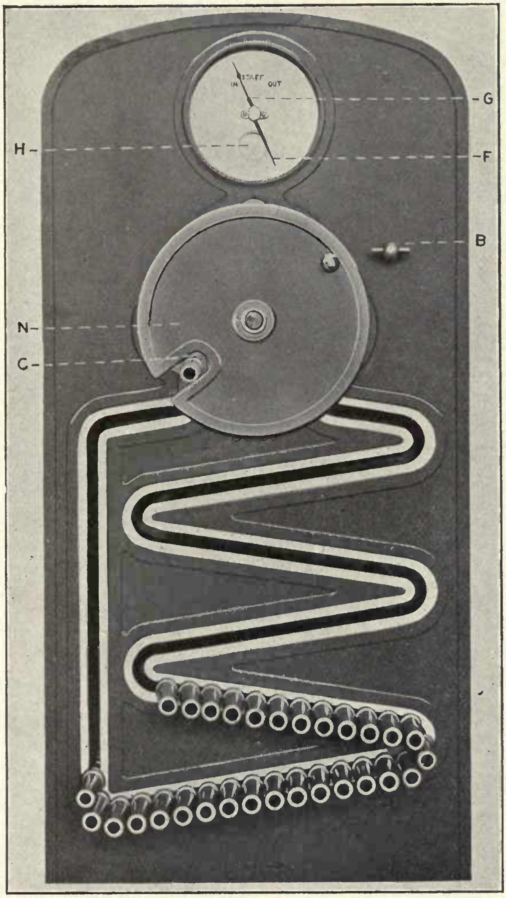


FIG. 35—FRONT VIEW OF STAFF INSTRUMENT WITH STAFF INSERTED IN DRUM AND OUTER GUARD

By rotating to position shown in Fig. 32 the staff may be released.

On arrival of the train at *Y* the staff is delivered either by hand or deliverer to the operator, who having seen that the train is complete by observing the rear end markers, places the staff in the opening *M* (Fig. 32) of his instrument having first turned the outer guard *N* (Fig. 32) to place, moves the staff into engagement with the drum, *D,* (Fig. 33), revolves it through one-half turn, using

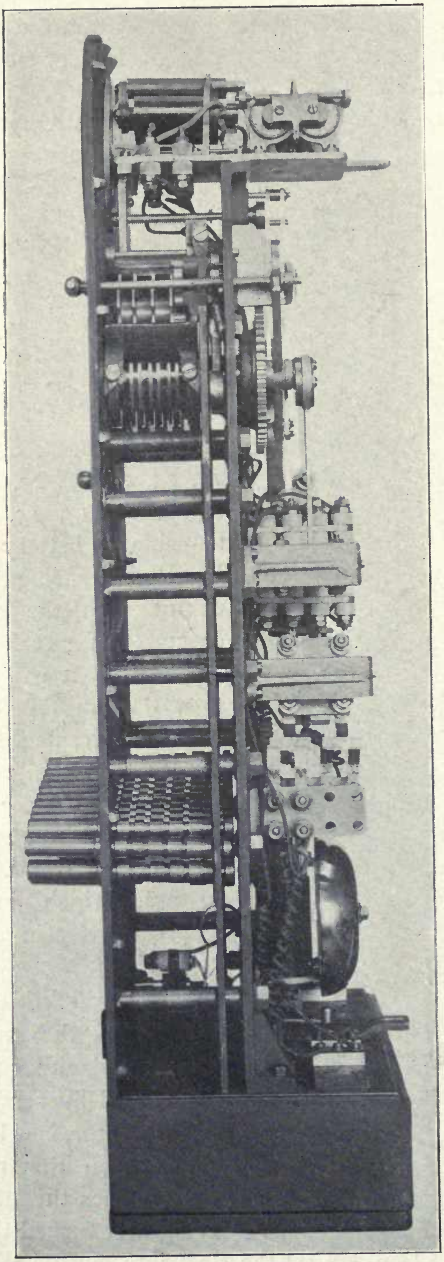


FIG. 36—SIDE VIEW OF STAFF INSTRUMENT SHOWING MECHANISM

the staff as a handle and allows it to roll down the spiral. He then presses his bell key the prescribed number of times, thus notifying *X* that the train is out of the section, which operation also moves the "staff indicating needle" at *X* from "Staff Out" to "Staff In." The operator at *X* presses his bell key in acknowledgment and by so doing moves the "staff indicating needle" at *Y* from "Staff Out" to "Staff In" (Fig. 39). The machines are now synchronized and another staff can be obtained from either in the manner above outlined.

The staff being put in the instrument at *Y*, the circuits are as follows: From + side of battery at Y through *19*, *20*, *21*, Bell key *A* closed at *Y* through *8*, *14*, *15*, *16*, *4*, *22*, *23*, *24*, *25*, *17*, *5*, *6*, *7*, *13*, *26*, to— side of battery at *Y*. Should a release be required, the preliminary spindle at *X* would be turned and current transferred from the bell to magnet *K 88* (Fig. 34) through the following circuit; from+side of battery at *Y* through *19*, *20*, *21*, Bell key closed at *Y*, through *8*, *14*, *15*, *16*, *4*, *22*, *23*, *27*, *28*, *25*, *17*, *5*, *6*, *7*,

13, 26, to—side of battery at *Y*. It will be seen that the current flowing through magnets *K 360* and *88* are again opposing each other, consequently, a staff can be released.

While it takes some little time to describe the method of operating the staff instruments, yet as a matter of fact, the removal of a staff actually takes less than five seconds and the operation of putting one in an instrument less than two seconds under ordinary conditions.

The same methods are followed at each succeeding staff station,

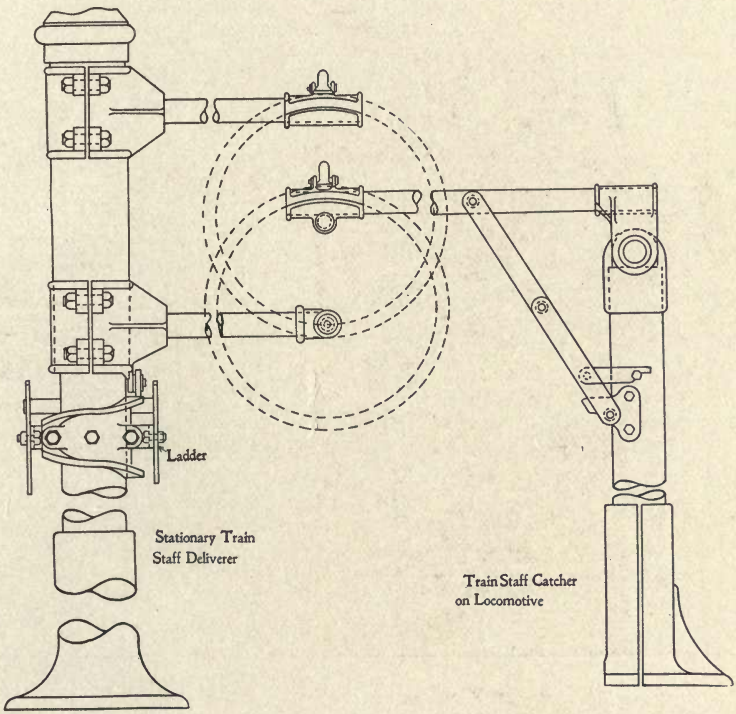


FIG. 37—APPARATUS FOR AUTOMATICALLY CATCHING AND DELIVERING TRAIN STAFFS SIMULTANEOUSLY AT HIGH SPEED

but no two adjacent sections use the same design of staff; that is to say, the staffs used between *X* and *Y* will not fit the instruments controlling the section between *Y* and *Z*. Usually four different designs of staffs are employed in actual practice to avoid any possibility of their being improperly used.

PERMISSIVE FEATURE

While the absolute system, where but one train is allowed in any section, is the ideal arrangement, yet cases occur where it is desir-

able to allow several trains to follow each other into the block at short intervals. This is known as the permissive system, and consists of an attachment (Fig. 40) to the absolute machine at each end of the section with *one* permissive staff. An absolute staff is always locked in a permissive attachment when it does *not* contain the permissive staff.

To operate this feature an absolute staff is withdrawn from the instrument at X in the usual manner and used as a key to unlock the attachment or base (Fig. 40) containing the permissive staff (Figs.

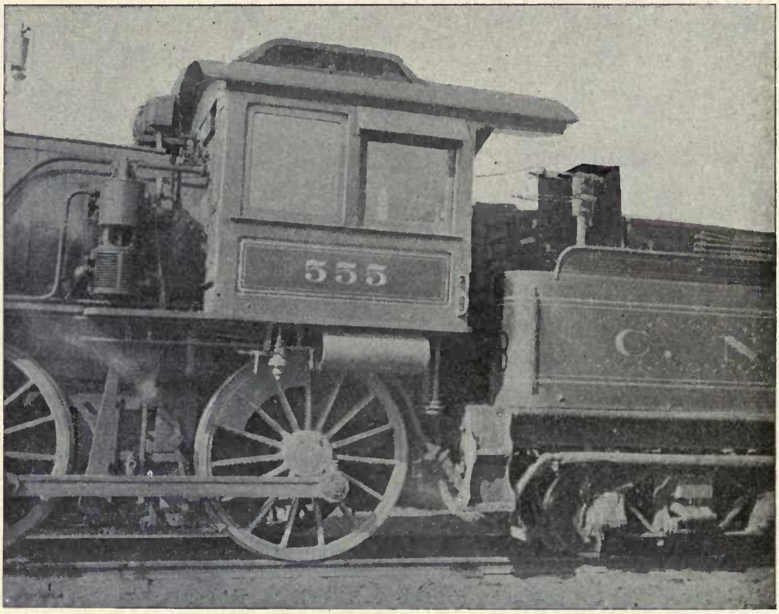


FIG. 38—TRAIN STAFF CATCHER MOUNTED ON LOCOMOTIVE TENDER

As used on the Cincinnati, New Orleans & Texas Railway on their fast express trains where the staff has to be caught at speeds frequently exceeding sixty miles an hour.

41 and 42) which is then taken out. The opening of the base and the removal of the permissive staff locks the absolute staff in the permissive attachment, there to remain until the permissive staff is replaced at either X or Y. The permissive attachment with outer case removed is shown in Fig. 44. The permissive staff consists of a steel rod and 11 removable rings

(Fig. 43) any one of which authorizes a train to pass through the section to *Y*. If less than 12 trains are to follow each other, the last one takes *all the remaining rings and the steel rod.* When all the rings and the rod are received at *Y*, the operator reassembles them into the complete permissive staff (Fig. 42) which he then places in the permissive attachment or base (Fig. 41) and locks it therein by the absolute staff already in the lock of this attachment. By so doing he releases the absolute staff which he restores to the absolute instrument in the regular manner. The machines are now synchronized and a movement can be made with the absolute staff in either direction and from *Y* to *X* with the permissive.

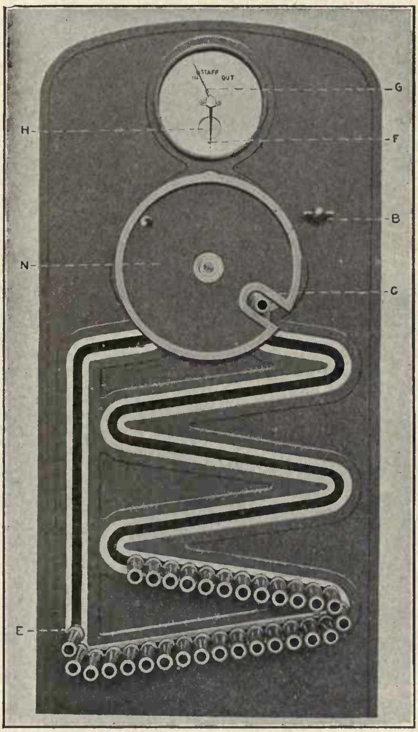


FIG. 39—FRONT VIEW OF STAFF INSTRUMENT WITH STAFF READY TO ROLL DOWN THE SPIRAL

If it is again found necessary to move several trains from *X* to *Y* under the permissive system, the permissive staff must be obtained by *Y* as before described and forwarded to *X* as a whole by the first train moving in that direction. When a train receives the entire permissive staff it confers the same rights as does an absolute staff.

CONTROL OF SIGNALS

In its capacity as a key the absolute staff has a number of uses in addition to that already described. Where signals are used to indicate to an approaching train whether or not it will receive a staff, an instrument known as the staff lever lock (Fig. 45) is attached to each lever operating such signals. To clear a signal the staff after being withdrawn is first used to unlock the lever lock (Fig. 45). The signal is then cleared and the staff removed from the lock and delivered to the train.

To insure the signal being placed at danger behind a train the act of unlocking the signal lever opens the staff circuit, and no communication can be made between the two staff stations until the signal is at danger, and the lever locked in that position. This does not indicate, however, that the operator will have the staff ready for delivery by hand, or in the mechanical deliverer. To cover this point an electric slot is attached to the signal governing train movements into the staff section, which slot is controlled by the staff and lever lock and the mechanical deliverer, so that before the signal can be cleared the staff must be released, used to unlock the signal lever and put in the staff deliverer, which closes the circuit on the electric slot. The signal can then be cleared. With this arrangement, therefore, a clear signal can not be given until the staff is actually in the deliverer.

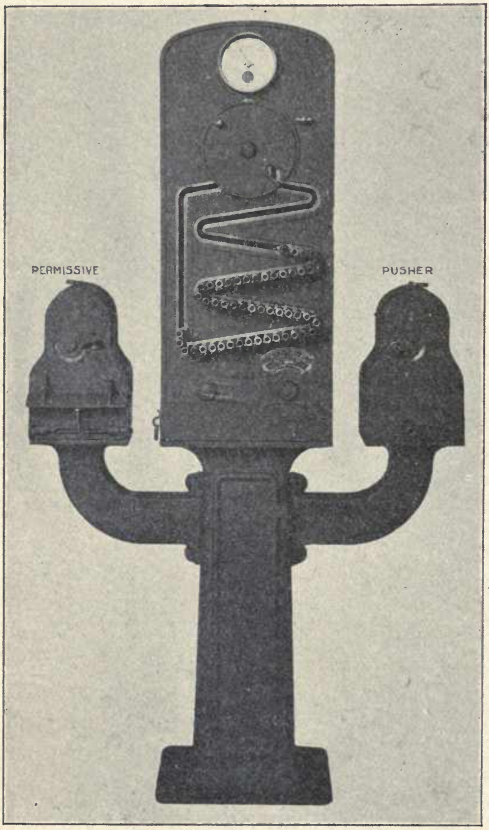


FIG. 40—FRONT VIEW OF STAFF INSTRUMENT WITH PERMISSIVE AND PUSHER ATTACHMENTS

When the train picks up the staff, the circuit on the slot is opened, automatically setting the signal to danger, which can not again be cleared until the operation described above is repeated.

SWITCH LOCKING

The staff is also used as a key to unlock siding switches which may occur between staff stations, the switch locks being so designed that the staff cannot be removed from the lock until the switch is set and locked for the main line, thus providing absolute protection against misplaced switches.

SIDING AND JUNCTION INSTRUMENTS

In some sections there is a siding of sufficient length to hold a train, but traffic would not warrant placing a staff at this point. That the usefulness of this long siding may not be lost, a special instrument is placed at the siding which enables it to be used for meeting or passing trains.

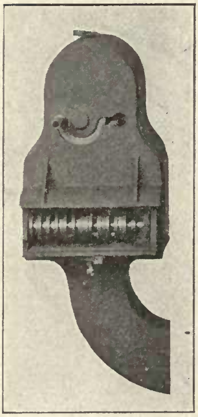


FIG. 41 — PERMISSIVE ATTACHMENT WITH STAFF RELEASED AND DOOR OPEN

FIG. 42 — PERMISSIVE STAFF ASSEMBLED

The operation is as follows: A train arriving at the staff station *X* has not time to proceed to Y, but can proceed as far as the siding. The operator at *X* gives the train a staff with instructions to proceed to the siding. Unlocking the switch with the staff, the train takes the siding, closes and locks the switch, places the staff in the siding instrument, and turns the drum to the right. The staff is now locked in the instrument, and the staff instruments at *X* and *Y* are synchronized, and the fact indicated to both operators so that trains may be sent through the section in either direction.

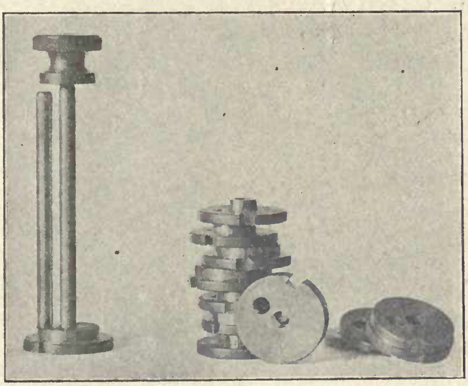


FIG. 43—PARTS OF PERMISSIVE STAFF

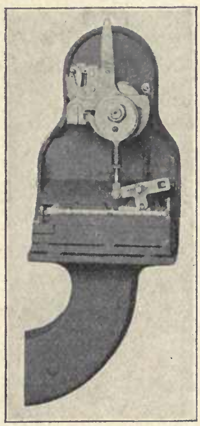


FIG. 44 — BACK VIEW OF PERMISSIVE ATTACHMENT SHOWING MECHANISM

When all trains having precedence over the one in the siding have passed through the section, and the staffs have been replaced in the instruments; *X* and *Y*

acting in conjunction can release the staff at the siding, which on being removed changes the circuits so that no staff can be released either at *X* or *Y*. The train on the siding then unlocks the switch with the staff and proceeds to *Y* or back to *X*.

A junction or diverging line may be situated between two points most suitable for staff stations; but on account of the small amount of traffic over the diverging line it would not be desirable to

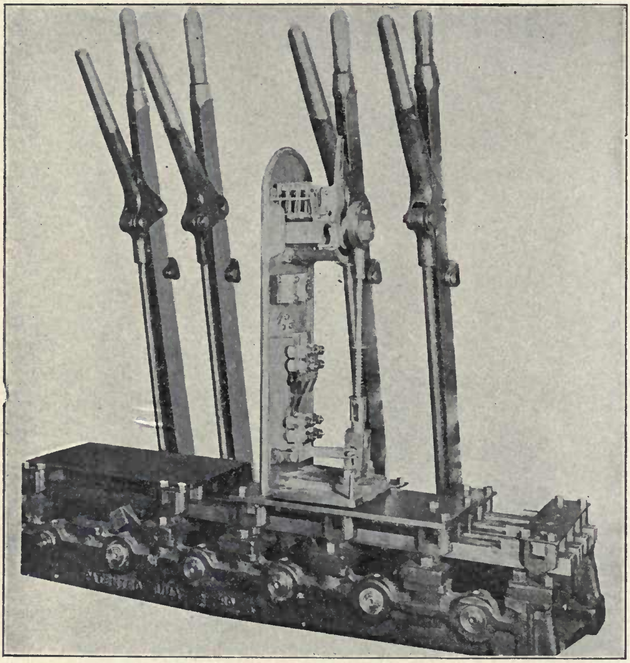


FIG. 45—VIEW OF STAFF LEVER LOCK WITH CASE REMOVED

make it a staff station. Such a point can be controlled in a similar manner.

PUSHER ENGINE ATTACHMENT

Another adjunct to the staff system is known as the pusher engine attachment and staff (Fig. 40) which is used on heavy grades where pusher engines are required, and is intended to both obviate the necessity of the pusher engine proceeding through the entire staff section, and to better equalize the traffic. It can readily be seen from the foregoing description of the staff system that under ordinary rules every train having a pusher engine attached would receive

one staff to proceed up grade as from *X* to *Y*. On arrival at *Y* the pusher engine would necessarily have to receive a staff to return to *X*. Supposing the traffic up and down grade to be equal and that each train going up grade requires a pusher, it is apparent that twice as many staffs would go down hill as came up, resulting eventually in all the staffs arriving at the foot of the grade, *X*, from which they could only be returned to *Y* by some special person authorized to unlock the instruments and remove the staffs by hand. Furthermore, the summit of the grade may be half-way between *X* and *Y*, but under the rules a pusher could not cut off at the summit and return to *Y*, but must continue on to *X* and receive a staff to return.

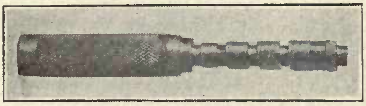


FIG. 46—PUSHER STAFF

To overcome these two objections the pusher attachment is employed. It consists (like the permissive attachment) of a separate device which may be attached to any absolute instrument (Fig. 40) and contains a staff of special design (Fig. 46) which can only be released by a regular staff, though, unlike the permissive staff, it can be out of its receptacle at the same time as the regular staff, but when so removed it opens the controlling circuits of the system, preventing any other movement being made until it has been returned and locked in the pusher attachment. Fig. 47 is a rear view of a pusher atachment showing the mechanism.

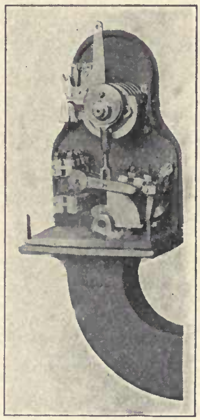


FIG. 47 — BACK VIEW OF PUSHER ATTACHMENT SHOWING MECHANISM

The operation is as follows: A train with a pusher wishes to proceed from *X* to *Y*. *Y* releases a staff at *X*, and *X* uses this staff to release the pusher staff. *X* then hands the regular staff to the train and the pusher staff to the pusher engineer. The train passes through the section and delivers the regular staff at *Y*. This is placed in the instrument there, the pusher engine retaining the pusher staff and returning to *X*. Until this latter staff is put into the pusher attachment at *X* and locked, the staff circuits are not re-established and no other staff can be released.

CHAPTER V

AUTOMATIC BLOCK SIGNALING

GENERAL

GIVEN a section of railroad from which large earnings are to be derived and assuming that there is plenty of business to handle, the problem is to move the maximum number of trains over it with economy and safety. If every train had a track of its own, no block system would be necessary, but on the leading railroad systems the traffic has increased much faster than the trackage. One of the most helpful and efficient means for safely handling a large number of trains over the same track is a good block system.

DEFINITIONS AND CLASSIFICATIONS

Before enlarging upon this subject, a few definitions may be of value to the reader.

A block is a length of track of defined limits, the use of which by trains is controlled by fixed signals.

A block signal is a fixed signal controlling the use of a block. The word "fixed" refers to location only since block signals are movable signals in fixed locations.

Block signals may be classified in three ways:

1st—As to the manner in which their day indications are displayed.

2d—As to the manner in which they are controlled and operated.

3d—As to what they control.

Under the first classification there are:

(a) Banner signals, the indications being displayed by a revolving banner.

(b) Disc signals, the indications being displayed by a movable disc in front of a fixed background; and

(c) Semaphore signals, the indications being displayed by the position of an arm moving in a plane at right angles to the track. In all types under class *one* the night indications are displayed by colored lights.

Under the second classification there are:

(a) Manual, the signal being controlled and operated by man

power. (b) Controlled manual, the signal being operated manually and constructed so as to require the co-operation of the signalmen at both ends of the block. (c) Automatic, the signal being operated by power which is controlled entirely by the presence or absence of a train in the block, or the condition of the track.

Under the third classification there are:

(a) Home block signal, a fixed signal at the entrance of a block to control trains in entering and using said block. The indications displayed by a home signal are "stop" and "proceed", or in some cases "stop", "caution" and "proceed".

(b) Distant block signal, a fixed signal used in connection with a home block signal to regulate the approach thereto.

An absolute block system is one which never allows more than one train in the same block at the same time.

A permissive block system is one which may allow more than one train in the same block at the same time, provided the trains are going the same direction and the second train has been warned by signal that another train is in the block.

EARLY BLOCK SYSTEMS

The older block systems in this country were all manual or manually controlled, following the practice in England and Germany. The enormous increases in the amount of traffic to be handled with only slight increases in trackage, together with the fallibility of the signalmen operating the signals, led to the development and use of automatic block signals. Briefly, both economy and safety led to this development. In the days when the station agent was ticket agent, baggage man, freight agent, freight handler, telegraph operator, etc., it was thought that to let him also handle the manual block signals would be good for him while he was resting. As traffic increased, these various duties became more and more onerous, the stations were not close enough together to be serviceable as block stations, and the men became too busy to handle the signals reliably.

The next move was to install block stations in the outlying districts. This meant a first cost of about $1 000 for the station and signals, and a yearly wage cost of not less than $1 000 to $1 500 for each block station. Furthermore, the men still made mistakes and gave wrong signals.

AUTOMATIC BLOCK SIGNALS

The automatic block signal must be a permissive signal in order that, if a signal is out of order and assumes the stop position, traffic

may not be entirely suspended for several hours. On double track lines this is not serious, as a train, after stopping at a signal out of order, may proceed with caution through the block expecting that another train is already ahead of it in the block, that a switch is misplaced or that a rail is broken. On single track lines it was thought that the delays might become serious, since when a train receives a stop signal it is necessary to protect it by sending a flagman ahead through the block. For this reason automatic blocking on single track has not met with general favor. The only two single track lines using this system extensively are the C. N. O. & T. P. Ry. and the Harriman Lines, the latter having installed several thousand automatic signals on single track. The Harriman Lines already claim to have shown that the expense of the system was warranted on account of the numerous cases of broken rails which have been reported by the automatic signals.

It is the purpose of this article to describe only the arrangements of signals in common use on double track lines and the automatic electric semaphore signal which is in most general use.

LENGTH OF BLOCKS

The ideal arrangement of automatic signals to secure the maximum capacity for train movements over a given piece of track would be to first decide upon the maximum distance required for stopping any train on the road. This can be decided from the air brake tests, and this distance would have to be the minimum length of the block. Since it is more difficult to stop on a descending grade and less difficult to stop on an ascending grade, the blocks would gradually be lengthened out on the descending grade and gradually shortened on ascending grades. As large terminals are approached the blocks would gradually be shortened on account of the limited speed of trains and congestion of traffic at such places. Having fixed the locations, the control of the signals should be such as not only to warn an engineman when he reaches a block which is occupied, but also to warn him in time to permit him to stop his train before reaching the entrance of the occupied block. With this arrangement and control of signals it would be possible to start two trains from one end of the line two blocks apart, run them the length of the road at the same speed and have them arrive at the other end still just two blocks apart. The second train would receive clear signals all the way; or if the first train should stop at any point, the second would receive due warning and would have plenty of space

to stop in before reaching the block which was occupied by the first train.

In ordinary practice to-day the minimum length of block is seldom used, and the length commonly varies from 4 000 feet to 12 000 feet. Frequently so little heed is paid to the principles mentioned above that the ideal arrangement is far from being reached. One of the principal reasons for improper spacing is that if a signal is located in its proper place for uniform spacing of trains, it cannot be readily seen on account of the curvature of the line or obstructions to the view, such as bridges. All of the diagrams of signal arrangement in Figs. 48 to 52 show the home signals as arms with square ends and the distant signals as arms with forked ends. In every case the block is the space between home signals, the distant signals being nothing more than repeaters for the home signals.

SEMAPHORES ON SEPARATE POSTS

Fig. 48 illustrates the arrangement of signals in an automatic block system using semaphore home and distant signals mounted on

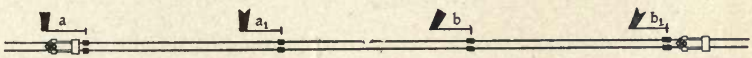


FIG. 48

separate posts. This arrangement is used very little excepting where traffic is light and the home block signals are considerably more than one mile apart. The distant signals would probably be located not more than 4 000 feet from their respective home signals.

A home signal is shown at *a* in the stop position with a train just past it in the block. The arm is horizontal and a red light would be displayed at night. It means "stop and wait the prescribed time (usually 1 minute) then proceed under control expecting to find a train in the block, a misplaced switch or a broken rail." The distant signal for *a* is shown at a_1 and is in the "caution" position. Some roads use a green light for the night indication; others use a yellow light instead. It means "expect to find next home signal in the stop position." *b* is a home signal in the proceed position. The arm is inclined at an angle of 60 or 75 degrees from the horizontal. On roads using green for "caution" a white light would be displayed at night. On roads using yellow for "caution" a green light would be displayed at night. It means "proceed, the block is unoccupied, all switches are set right and rails are unbroken." b_1

is the distant signal for b and is in the proceed position. On roads using green for "caution" a white light would be displayed at night. On roads using yellow for "caution" a green light would be displayed at night. It means "proceed, expect to find the next home signal in the proceed position."

Using this arrangement, trains can run at speed if spaced a distance equal to one block (a to b) plus the distance between a home

FIG. 49

signal and its distant (b to b_1) or ordinarily about 10 000 feet + 4 000 feet = 14 000 feet apart.

On most roads the blocks do not often exceed 7 500 feet in length and it has been found convenient as well as economical to use the arrangement shown in Fig. 49, which shows home and distant signals mounted on the same post.

SEMAPHORES ON SAME POST

The indications and meanings of the signals shown in Fig. 49 are identical with those described in Fig. 48. It is developed by shortening the length of blocks a b in Fig. 48 until a_1 and b are so close together that it is best to mount them on the same post. With

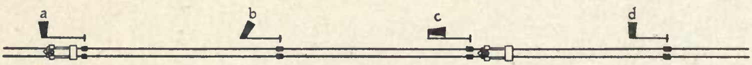


FIG. 50

this arrangement trains running at speed would be spaced two blocks apart, although the actual distance might be the same or less than that shown in Fig. 48.

THREE POSITION SIGNALS

Fig. 50 illustrates the arrangement and use of three position signals. Each signal is a home signal and distant signal combined. a is a home signal in the "stop" position. The arm is horizontal. The meaning is the same as a in Fig. 49. The night indication is the same as a in Fig. 48. b is a home signal in the "caution" position. The arm is inclined at an angle of 45 degrees from the horizontal. The meaning is the same as ba_1 in Fig. 49. The night indication is the same as a_1, Fig. 48. c is a home signal in the "proceed" position. The arm is inclined at an angle of 90 degrees from the horizontal.

The meaning is the same as cb_1, Fig. 49. The night indication is the same as *b,* Fig. 48.

The semaphore signal is primarily a position signal, yet in Figs. 48 and 49, both arms a and a_1 are in the horizontal position but have two entirely different meanings. The signals shown in Fig. 50 are

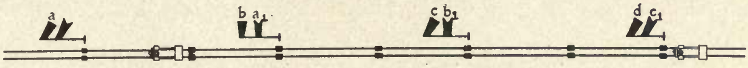


FIG. 51

theoretically more correct in this respect. Both schemes are extensively used, both have arguments in their favor, and both have many ardent advocates. As far as the spacing of trains is concerned, Figs. 48 and 49 are exact equivalents.

OVERLAP SYSTEMS

Partial block length—An "overlap" system, as shown in Fig. 51, is one in which each home block signal is so controlled that it will remain in the stop position until the train has passed a certain prescribed point in advance of the next home signal. It has been used in arrangements like Fig. 48, but presupposes that conditions may arise which may cause an engineman to run by a home signal in the stop position without making the stop and gives him additional space to stop in. It is very questionable as to whether it should be used except in unusual cases where the blocks are, on account of traffic,

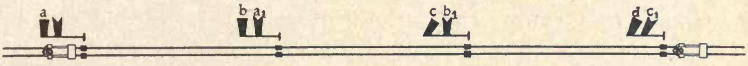


FIG. 52

very short and it is doubtful as to whether a train can stop in the length of one block only. This system is open to the objection that, if an engineman knows that there are at times two stop signals between him and the preceding train, he may assume that there are always two stop signals between and run by the first without attempting to stop.

If, as in some of the earliest installations, home signals only are used, the overlap is necessary because in many cases local conditions will not permit the location of signals so that they are visible a safe stopping distance away. The distant signal takes the place of the overlap except where the blocks are extremely short. With the arrangement shown in Fig. 51, trains would be spaced two and one-half blocks apart.

Full block length—Another overlap system is shown in Fig. 52 which differs from Fig. 51 in that the overlap is a full block in length. With this arrangement trains would be spaced three blocks apart. This system is used in the New York Subway. There the blocks are only 800 feet long and there is a full block overlap and each signal has an automatic train stop working in conjunction with it.

In the foregoing description the spacing of trains refers to their spacing if they are running at speed past all signals in the proceed position. In Figs. 48 to 51 the second train would not have to actually stop until it reached the signal *a*. In Fig. 52 the second train would not have to stop until it reached the signal *b*.

CONSTRUCTION

Counterweights—All automatic signals must be so constructed that the weight of all moving parts tends to restore the signal to the stop position. To secure this with all of the signals illustrated the semaphore arm has to be counterweighted. The counterweight must be sufficient to carry the arm to "stop" even when it is covered with snow and ice.

It is plain that, if the arm traveled in a quadrant above the horizontal, little counterweight would be necessary and the arrangement would be safer and more economical of power. Recently signals having arms working in the upper quadrant have been installed on the Pennsylvania railroad and the scheme is being urged on many other roads. In such an arrangement the meanings of the signals would correspond with the meanings of arms at equal angles in the lower quadrant.

If an automatic signal is so counterweighted that it will go to the "stop" position by the force of gravity, it is evident that it must be moved to the "proceed" position by the application of power and held there by power. Before going into the construction of the signals themselves it is well to see how a train in passing a signal in the proceed position cuts off the power so that gravity returns it to the "stop" position.

The track circuit—The track circuit is the foundation of every automatic block system. It is its main element of strength and it is also one of its weakest elements if we are to consider the many annoying troubles which arise from it. The track circuit was invented in 1872 and has been used in all kinds of signaling and protective schemes. The installation of a section of track circuit is very sim-

ple. It merely means the removal of one of the iron fish plate joints from each rail at each end of the section and replacing them with one of the many types of insulated joints; the bonding together of the intermediate rails by running bonds of No. 8 galvanized iron wire around each joint and connecting a battery across the rails at one end and an electro-magnet across the rails at the other end. From the diagram in Fig. 53 it may be seen that this would form a closed circuit, the rails simply connecting the battery to the electro-magnet. This electro-magnet is called a relay. It has a pivoted armature weighted so that it will fall away from the cores by gravity and the magnet must be energized to raise it. The moving armature carries moving contacts for controlling auxiliary electric circuits and is used to control the operating circuit for a signal. The wheels of the train when on the track circuit offer so little resistance to the current that the relay does not get enough current to

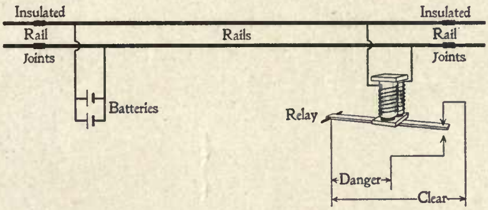


FIG. 53

hold the armature up. It then falls and opens the signal operating circuit.

While the track circuit is fundamentally very simple it has been very difficult to make the arrangement operate under all conditions for the following reasons:

1st—There is no insulation between rails except the ties and ballast and during wet weather the leakage between rails is considerable.

2nd—The source of current is usually a gravity battery, although in recent installations some storage batteries are used. The voltage and current capacity in the case of the gravity battery are low and the problem is to arrange the cells so as to furnish enough current to feed the leakage between rails and also feed the relay enough current to operate it satisfactorily in wet weather.

The actual figures in regard to the amount of power used to operate one track circuit seem ridiculously small to an electrical engineer. For instance, the total amount of energy expended for one

track section is seldom more than one-half of a watt. The amount needed to operate the relay is less than one-fourth of a watt. Yet it is a difficul task to hang on to that one-half watt through from 2 000 to 5 000 feet of track with low insulation between rails.

The voltage used is ordinarily from one to two volts. If the voltage is increased much above this the leakage is so excessive that the gain at the relays is very little. If the resistance of the relay is much above nine ohms the relay will not work in wet weather. If the resistance is much below four ohms the train will not cause it to open.

The energy expended is divided in some such way as this:

Ten percent is used to overcome resistance of rails and connections to battery and relay.

Fifty percent is lost by leakage.

Forty percent is used in operating the relay.

3rd—The relay must be inclosed and sealed so that careless maintainers cannot adjust or tamper with it, and moisture cannot get on the contacts moved by the armature and freeze them closed. It must be protected by high grade insulation in all its parts so that lightning cannot fuse its contacts, and must also be protected by a first class lightning arrester.

CHAPTER VI

AUTOMATIC BLOCK SIGNALING

DIRECT CURRENT

IN GENERAL, all signal circuits should be so arranged that a closed circuit is employed to give all safety indications and the operating battery should be at the end of the circuit farthest from the apparatus, in order that any crossed wires, broken wires or loss of power will cause a danger indication.

The simplest system of circuits is the polarized track circuit system shown in Figs. 1 and 2. Fig. 1 illustrates the application of the polarized system to an arrangement of signals where the home and distant arms are mounted on the same post. *H′* shows the wiring at the last signal of the system which would have no signal in advance and consequently no distant arm.

The home arm at this point is controlled through the contact of a neutral relay, *R*, connected to the track section in advance of it. The battery for the track section in the rear, instead of being connected direct to the rails, is carried through a pole changing circuit controller which is operated by the signal arm. With the arm in the stop position the pole changer would shift the battery from *AD-BC*, as shown in heavy lines, to *AC-BD* as shown in dotted lines, thus reversing the polarity of the battery as applied to the rails. *H* shows the wiring at all other signal locations. The home arm is controlled through contact *K* of relay *R*, the same as the home arm at *H.′* Contact *K* is called the neutral contact and is open or closed depending upon the amount of current flowing through the electro-magnet coils, and not by its polarity.

Contact K′ is operated from another armature on the same relay. This armature is a permanent magnet which swings to either pole of the electro-magnet of the relay and thus shifts the contact K′ whenever the polarity of the electro-magnet changes.

The distant arm is controlled through both *K* and *K′* so that the distant operating circuit will be closed whenever the home arm in advance has been cleared and the battery on the track is of the polarity shown. The distant arm is also controlled through a circuit controller operated by the home arm on the same post.

Fig. ~~55~~ 2 shows the same scheme applied to an arrangement of signals where the home and distant arms are mounted on separate posts.

~~Fig. 56 shows a sectional view of a neutral type of relay.~~

Fig. 57 shows a sectional view of a combined neutral and polarized type of relay.

If it is assumed that there is a train in the section in advance of *H,'* the home arm at *H '* would be in the "stop" position and the battery would be reversed on the track section *HH.'*

At *H* the contact *K* would be closed and the contact *K '* would be open so that the home arm would be in the "proceed" position and the distant arm would be in the "caution" position. When the train passes out of the section and the home arm at *H '* goes to the proceed position, thus reversing the polarity of the battery on the track section *HH '*, it may be noted that while the pole changer is shifting, i. e., for a fraction of a second, the relay at *H* would be deenergized and the contact *K* would open and then close. This opening of contact *K* would tend to release the home arm at *H* and return it to the "stop" position if provisions were not made to prevent

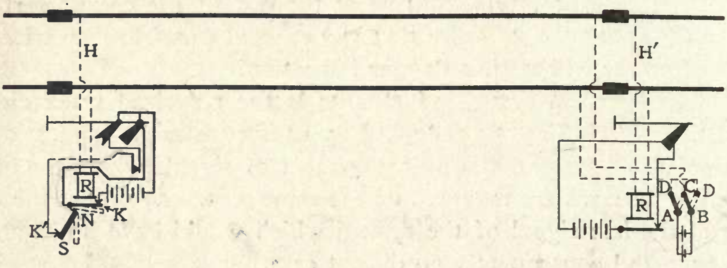


FIG. 54

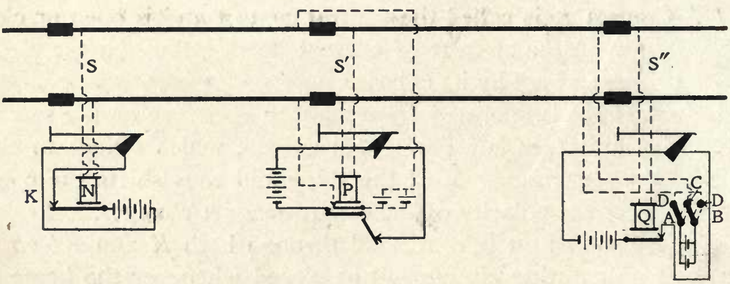


FIG. 55

it. This is prevented by applying a closed circuit inductive coil to the relay *R* or to the holding magnet of the signal, either of which will hold the signal arm clear momentarily by induction. If this slow releasing feature is applied to the relay, the contact *K* will remain closed long enough for the pole changer to shift. If it is ap-

plied to the holding magnet of the signal it will hold the arm long enough for the pole changer to shift in spite of the fact that K may open for an instant. The latter scheme is usually employed. go to pg

Another automatic block signal system which is if anything better suited to meet all around conditions than the polarized system provides for the control of distant signals by line wires as shown in Fig. 58. The home arms are controlled directly from the track relays as previously described but the distant arm a_1 is controlled through an additional relay R_2 which in turn is controlled through line wires and a circuit controller (c) operated from the home arm a in advance. The distant arm is also controlled by a circuit controller operated by the home arm b on the same post. The line

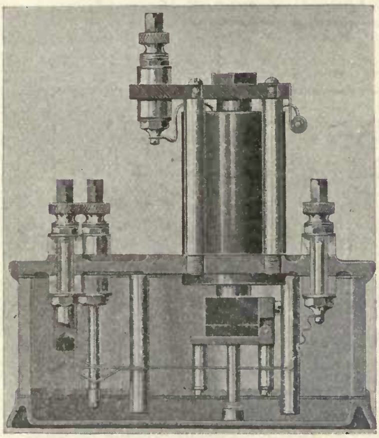


FIG. 56—SECTIONAL VIEW OF NEUTRAL TYPE RELAY

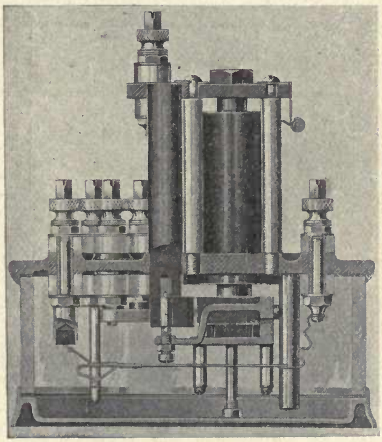


FIG. 57—SECTIONAL VIEW OF COMBINED NEUTRAL AND POLARIZED TYPE RELAY

wires have to be protected with lightning arresters but even then the distant arms are frequently out of service on account of lightning. For this reason other schemes which provide for the control of the home arms through line wires are objectionable and cause unnecessary delays to traffic.

Fig. 58 also shows what is done when the track section between signals is too long to operate as one section. It may be noted that the track circuit is relayed at the cut sections by a method somewhat similar to that employed in telegraph lines. Usually from 3 000 to 5 000 feet of track can be operated without a cut. Stop The signal operating batteries B and B' each consist of 16 cells of caustic potash

primary battery, connected in series and housed in a receptacle placed sufficiently deep to prevent freezing; or they might each consist of five cells of storage battery in an iron case beneath the signal operating mechanism. The track batteries B_2-B_3 consist of two or three cells of gravity battery connected in multiple and placed in an iron chute below the frost level. One cell of storage battery with from one to two ohms resistance in series with it may be used instead. Fig. 59 shows a cut section of a typical battery and relay shelter. Storage batteries give the best results on both track and signal operating circuits, but their first cost is usually greater.

Fig. 60 shows the signal operating mechanism now almost exclusively used on the leading railroads. About 25 000 are in use. It consists primarily of a motor and an electric clutch or holding

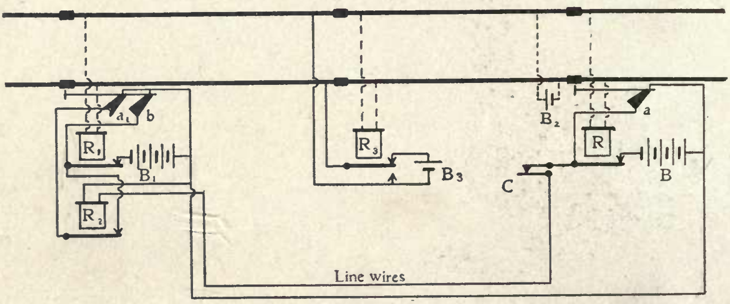


FIG. 58—DIAGRAM OF CONNECTIONS WHEN TRACK CIRCUIT RELAY IS USED

magnet, the latter being mounted on a compound lever to which the operating rod of the signal arm is attached near the center. This compound lever is pivoted near one end and the motor, through a train of gears, drives a chain carrying a trunion which engages with the free end of the lever and raises it when the operating current is applied to the motor and magnet. After the arm is raised the motor is automatically cut out and stopped by a friction brake. The end of the lever then drops back a little and rests on a catch where it is held, free from the motor gearing and chain, until the magnet is deenergized by the opening of the control relay. When the magnet is de-energized the lever arm drops down by gravity because the armature of the magnet releases the train of levers in the arm and thus releases the end of the arm from the catch. The fall of the lever arm is eased by means of the dash-pot connected outside the pivot end.

Fig. 60 shows a two arm movement, the lever arm at the front

being lifted to operate the home signal arm and the lever arm at the back being down with the distant signal arm in the "caution" position. Beneath the clutch, or slot magnet, as it is called, is the pole changer operated by the home signal lever arm.

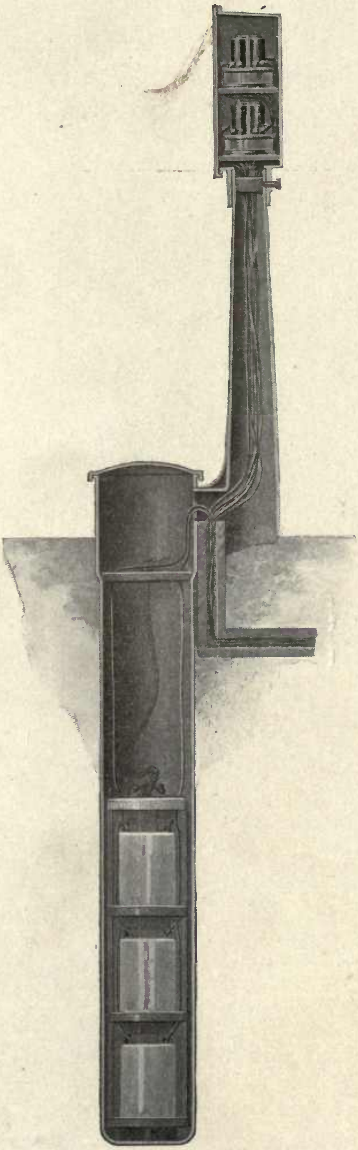


FIG. 59—SECTIONAL VIEW OF BATTERY AND RELAY SHELTER

The leverage is such that the armature of the slot magnet has to hold up only from one to three pounds, although the combined load of operating rod, signal arm and slot lever arm is over 100 pounds. The slot magnets are compound wound, a low resistance winding being in series with the motor and cut out with it, and a high resistance winding (500 to 2 000 ohms) being in multiple with the motor to hold the arm after the motor cuts out.

The operating voltage is usually about ten volts, the time required for operating one arm about six seconds, and the motor current about two amperes.

This mechanism is exceptionally free from friction, the armature of the slot magnet is far enough from the core so that it cannot be held by residual magnetism and the weight of all moving parts tends to restore the signal to the stop position as soon as the track relay cuts off the battery current.

The protection of switches in block signal territory has been left to the last in order that the main scheme might not be confusing. Each switch is insulated so that the track circuit passes through it unbroken. A circuit controller such as shown in Figs. 61 and 62 is

attached to the point of the switch and adjusted so that if the switch is open one-fourth of an inch the track circuit will be short-circuited as if by the presence of a train. For the guidance of trains coming out of a siding onto the signaled track, a switch indicator mounted on an iron post near the switch is employed. The switch indicator is usually so controlled that when a train is approaching

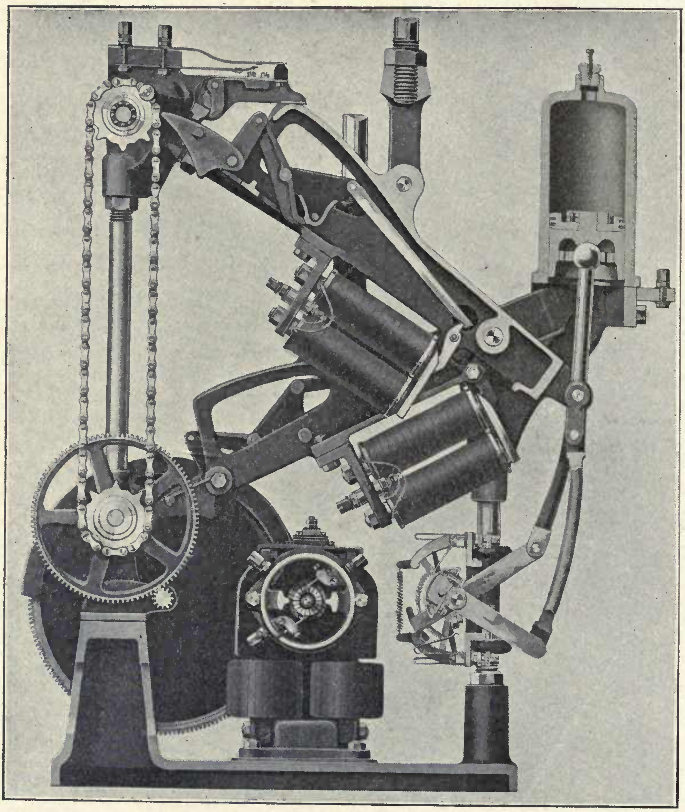


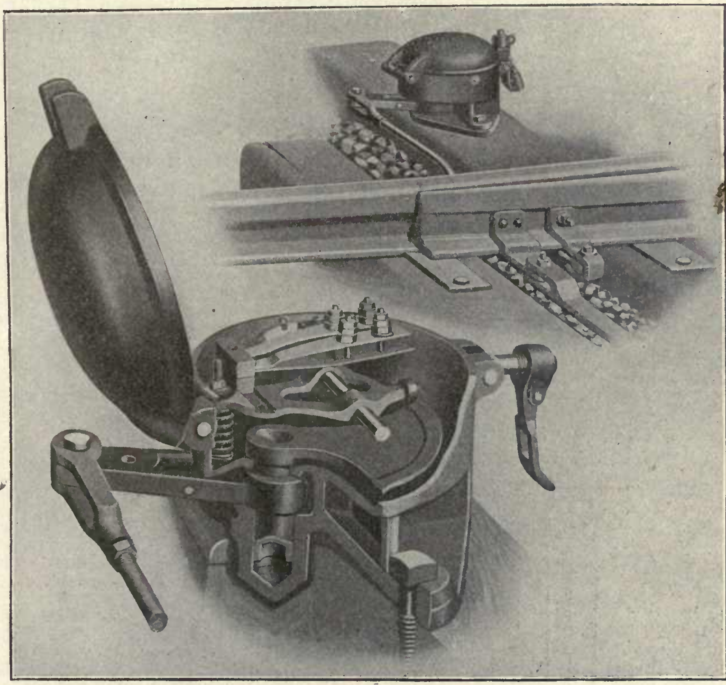
FIG. 60—ELECTRIC SIGNAL OPERATING MECHANISM

The right hand rod at the top connects with the home signal arm and the left hand rod connects with the distant signal arm. There is a second chain back of the one shown for operating the distant lever arm.

on the main track two blocks away the miniature semaphore is set to the "stop" position to warn the train in the siding not to open the switch. All sidings are made a part of the track circuit up to the

fouling point to protect trains on the main track from cars which may not clear it.

The average cost for an automatic block system using home and distant signals on the same post is from $750 to $1100 per block section, depending on the length of block, number of switches



FIGS. 61 AND 62—VIEW OF CIRCUIT CONTROLLER APPLIED TO SWITCH AND ALSO IN DETAIL

and method of signal control. The average cost of maintenance and operation of such a system is from $75 to $100 per two-arm signal per year.

CHAPTER VII

AUTOMATIC BLOCK SIGNALING—ALTERNATING-CURRENT

GENERAL

THE proper operation of a direct-current track circuit may be interfered with when the track rails have the additional duty of conducting current for other purposes, such as the propulsion of trains. It has, therefore, become necessary to use a kind of signaling current in the rails which, while performing the functions previously described, will in addition be able to operate a track relay selectively; i. e., which will respond to the signaling current

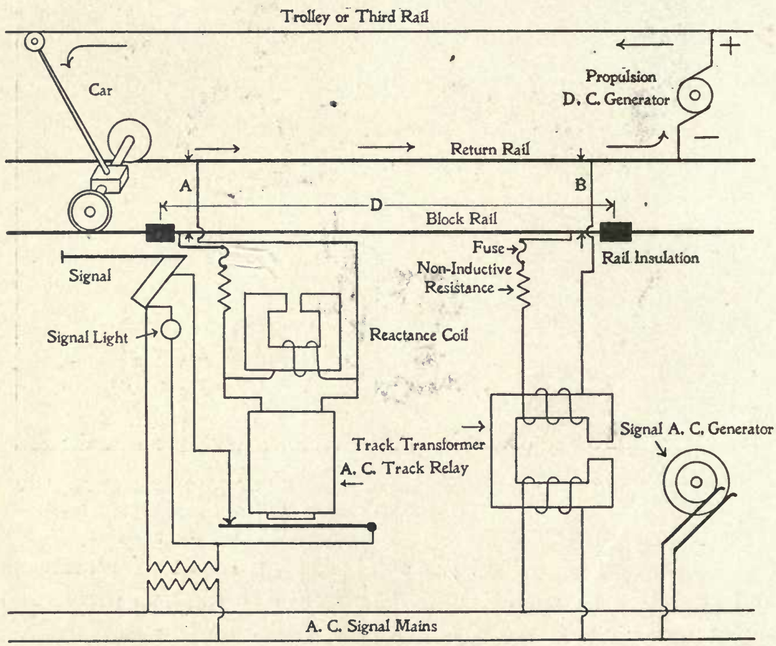


FIG. 63—TYPICAL ALTERNATING-CURRENT TRACK CIRCUIT USING THE SINGLE-RAIL SCHEME

and to no other. Thus alternating current, because of its inductive properties, has been substituted for direct current.

Two schemes of alternating current are in use, the single-rail return system and the double-rail return system. In the former, one rail of each track is insulated into block sections for signaling

purposes, the other rail serving as a continuous return for the power current and as one side of the alternating-current track circuit. In the latter, both are insulated into block sections and both are used for the power current. This is accomplished by the use of balanced inductive bonds and is used in preference to the single-rail system under certain conditions. The single-rail scheme and some features of interest in its application will be considered in this article.

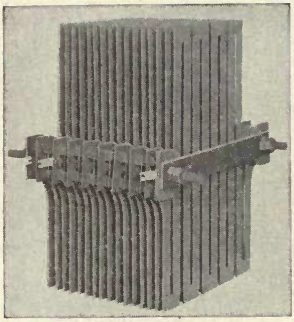


FIG. 64—FORM OF GRID USED FOR NON-INDUCTIVE RESISTANCE

SINGLE-RAIL SYSTEM

Fig. 63 shows a typical alternating-current track circuit using the single-rail scheme, and its relation to the propulsion system. As practically all of the propulsion current flows through the return rail within the distance, *D,* the length of the block, and relatively little through the block rail, there will be a drop in voltage in the former and not in the latter. This drop appears at *A* and at *B,* the sum of which will equal *D.* Thus a small amount of propulsion current will flow through a track relay at one end of the section and through the secondary of the track transformer at the other, the effect of which is to magnetize the iron of each to a certain extent and, if excessive, to diminish the influence of the alternating signal current. In order to limit this effect of the propulsion current on the relay, a non-inductive resistance, ~~Fig. 64~~, is connected in series with the relay and a reactance, ~~Fig. 65~~, of low ohmic resistance in multiple with the relay. In like manner the track transformer, ~~Fig. 66~~, is protected by a non-inductive resistance in series with it. As a further precaution against the magnetizing effect of the propulsion current, the iron of both transformer and reactance coil is provided with an air gap. In case of a short-

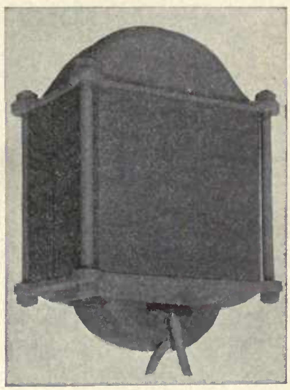


FIG. 65—LOW RESISTANCE IMPEDANCE COIL

circuit between the power and block rails, fuses protect the apparatus from injury. The resistance in circuit with the transformer secondary serves the further purpose of limiting the flow of alternating current when the rails are short-circuited by a train.

The type of alternating-current relay used with the single-rail scheme ~~is shown in Figs. 67 and 68 and~~ consists of a movable aluminum disc or section of a disc passing between the poles of a magnet. A part of the pole faces are enclosed by a closed conductor thus causing a distorted field which by the repulsion between it and the field set up by the eddy currents induced in the disc causes the necessary mechanical movement of the disc. The shaft upon which this disc is mounted carries contact parts (at a short radius) which operate to control other circuits which operate the signals.

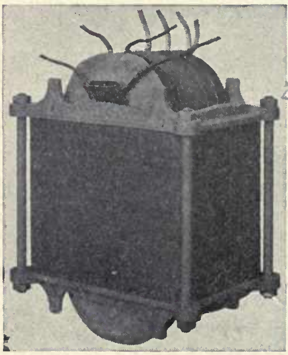


FIG. 66—TRACK TRANSFORMER WITHOUT CASE

When a block is not occupied by a train, the drop in propulsion voltage *D* (see Fig. 63) is divided between *A* and *B* in proportion to the ohmic resistance of the apparatus connected across the rails at those points, the drop in the block rail being relatively negligible. This is the case also when a train is in the middle of the block. When, however, a train is at A, both the block and return rail are at the same potential at that point because connected by the wheels and axles, which also shunt the relay. Drop *D* now appears at *B,* thus creating perhaps the most unfavorable condition for the transformer, for it now receives the maximum direct current from the track while delivering an increased amount of alternating-current. When a train is at *B* the transformer receives no direct current and delivers the maximum alternating current. Simultaneously the relay receives direct current due to the total drop *D*, and it would not matter if its iron were saturated. for alternating current is not present because a train occupies the block, hence the relay is properly inoperative and the signal indicates danger.

The means provided to protect the track transformer and relay from the effect of the propulsion direct-current drop, limits to some extent the useful effect of the alternating-current in the track cir-

cuit. Clearly then there is a limit to the amount of direct-current drop under which an alternating-current track circuit of given length will be operative with the single-rail scheme. Fortunately this point has not been reached in practice, for a loss of energy in a rail return system sufficient to disable the alternating-current track circuit could not ordinarily be tolerated.

In the single-rail scheme the amount of alternating signal current in the track rails is relatively small so that its drop in voltage between the transformer and relay is not serious. The insulation resistance between the block rail and return rail is another factor

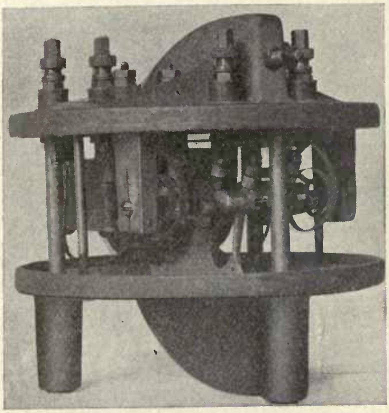


FIG. 67—ALTERNATING-CURRENT RELAY WITH GLASS COVER REMOVED

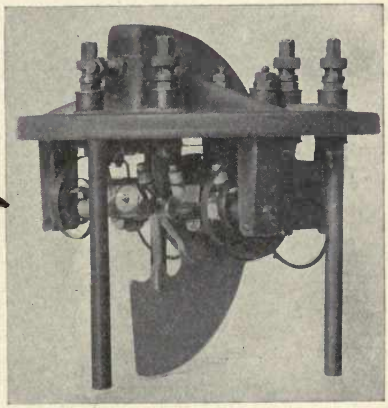


FIG. 68—RELAY WITH BASE REMOVED, SHOWING MOVABLE VANE

greatly affecting the operation of the track circuit. Not only does this decrease as the length increases, but it varies greatly with weather and other conditions. The expedient of increasing the transformer capacity to overcome leakage difficulties (occasionally as low as two ohms per thousand feet of track) is not wholly advantageous because increasing the alternating-current track voltage at the transformer increases in like proportion the leakage current from block to the return rail, and it increases the alternating-current drop in the rail because of this increased current, so that the relay is not greatly benefited. It is better to reduce the length of the track circuit where necessary, as that is more beneficial in every way. This does not necessarily mean that the block must be shortened for the track between the signals may be subdivided into a number of track circuits, each one of which controls the signal. It may be seen that the signaling equipment is in a sense a compromise

with respect to a number of conditions which are conflicting and which to some extent cannot be known in advance. Experience thus far has not presented track conditions requiring more than one track circuit between signals. A number have been in service more than three years which are about one mile in length and give no trouble.

APPLICATION OF THE SINGLE-RAIL SYSTEM

The most notable installation in which the single-rail alternating-current track circuit is used is that of the New York Subway. In this the automatic block signals, Figs. 69 and 70, automatic train stops, Fig. 71, and interlocking switch and signal plants, (the latter

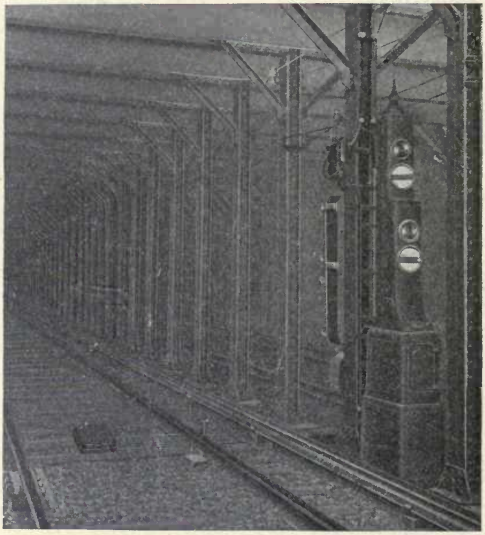


FIG. 69—FRONT VIEW OF A TYPICAL BLOCK SIGNAL IN THE NEW YORK SUBWAY

signals being semi-automatic) are of the electro-pneumatic type. The track relay control circuits which in turn control magnetically operated pin valves governing the admission of air to the cylinders which actuate the signals and train stops. In this installation the two alternating-current signal mains carry current at 500 volts and 60 cycles. To these mains are connected the primary leads of the track circuit transformers which step down by one secondary winding to ten volts for supplying the track circuit, and by another secondary winding to 55 volts for the signal lights. The non-inductive resistance of one ohm between the track rails and the ten-volt sec-

ondary causes a drop of about two and one-half volts, so that the alternating-current potential across the rails opposite the transformer is seven and one-half volts. A similar resistance in series with the alternating-current track relay at the opposite end of the block causes an additional drop of two volts, reducing the voltage of the relay to about five volts which allows one-half a volt for drop in the rails. These values are only approximate.

The alternating-current energy required per block may be summed up as follows: That for the signal lights, the one ohm resistances and the leakage (from rail to rail), non-inductive, and that for the track transformer, the impedance of the rails, the track relay and the impedance coil connected across the relay terminals, partially inductive. The power-factor of the whole is about 80 percent and the load per average block with average traffic, 80 watts.

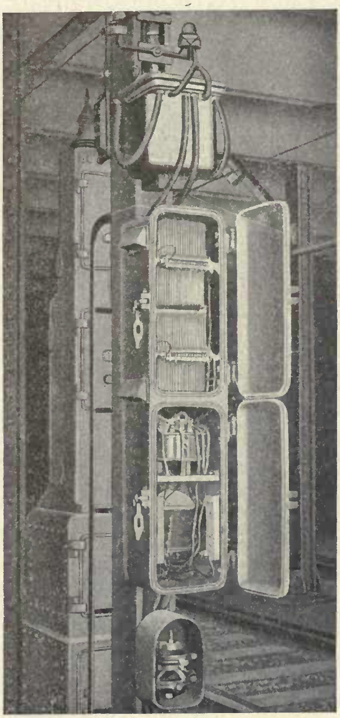


FIG. 70—SIGNAL APPARATUS—REAR VIEW*

In order to secure the greatest safety as well as density of traffic on the express tracks and at curves on the local tracks, the signals were placed at intervals as close as the braking distance of a train plus a reasonable margin of safety would permit. The element of personal error on the part of the motorman was eliminated by the automatic stops, Fig. 10, which apply the brakes when he fails to observe a danger indication of the signal. It has been found, however, that the moral effect of this train stop is very great, for no motorman will carelessly invite the censure of his employers and the public

*This figure shows the details of the alternating-current signals as applied to the Subway in New York. The track transformer is at the top. Beneath it is the instrument case containing the grid resistances, track relay and reactance coil. Below the case is the electro-pneumatic valve for controlling the automatic train stop.

by a non-observance of the signal thus made conspicuous by the noise of escaping air and the sudden stoppage of the train.

In such a case, the only question of veracity at issue is whether the stop was in the danger position while the signal indicated safety, a situation which exists when some part of the stop mechanism or its controlling circuits are deranged. To avoid serious delay to traffic when the stop apparatus is out of order, means are provided whereby a guard may hold the stop in the clear position while his train pulls over it, but as soon as this act of the guard ceases the stop returns to the danger position.

The remarkable record of performance of the signal system in the New York Subway is worth noting. The failures due to all causes, many of which are not directly chargeable to the signal apparatus, are about one to every 400 000 signal operations. Some months it is not so good while in others it is even better.

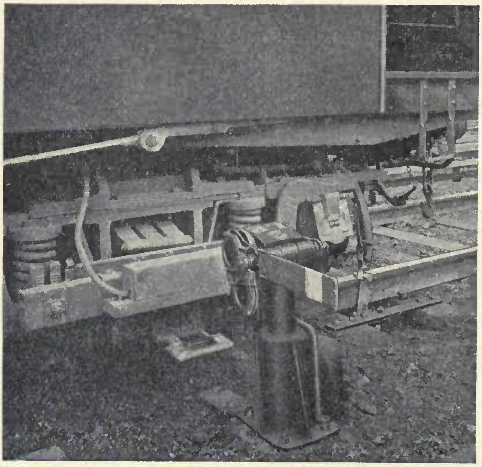


FIG. 71—DWARF SIGNAL AND AUTOMATIC TRAIN STOP

ALTERNATING-CURRENT SIGNALING ON STEAM ROADS

Recent developments indicate that alternating-current signaling will have a large field on steam roads. This is primarily due to the trouble experienced with foreign direct currents, chiefly from trolley cars, which interfere with the battery current commonly used in the track circuit. For this purpose alternating current at a frequency of 25 cycles is most desirable because of the relatively low impedance in the line wires and track rails due to reactance. No inductive bonds at the ends of the track circuits are required; hence the necessary alternating current in the rails is limited to the needs of the track relay and leakage from rail to rail. By the use of a relay of special design requiring a very small amount of current to operate, the total current in the rails is so small as to cause but little drop, which permits of the use of a long track circuit.

Alternating-current signaling on steam roads lends itself readily to the wireless control of distant signals, without the use of permanent magnets and the danger of residual magnetism.

In this connection, it should be noted that with the alternating-current relay the shunting voltage is practically the same as the pick-up voltage. Incidental but important advantages of the use of the alternating-current for signaling steam roads are that the signals may be operated and lighted by alternating-current taken from the mains which supply the track circuit. Thus all batteries are eliminated as well as oil for the lights and the services of lampmen.

One two candle-power, four and one-half watt lamp per signal blade gives better illumination than the average oil light and it does not smoke the lenses nor blow out. The lights may be allowed to burn continuously night and day, as it ordinarily would not pay to turn them off because of the small energy required and the long life of such lamps. The signals may be operated by induction motors (having neither brushes nor commutators) and the slot magnets likewise may be operated with alternating current.

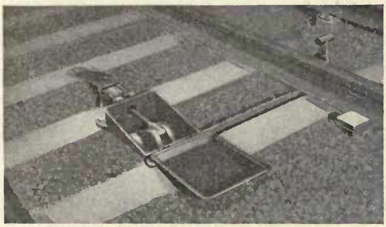


FIG. 72—DETAILS OF AUTOMATIC TRAIN STOP

The foregoing considerations, in addition to the chief advantage of non-interference of foreign current in the track circuit, are all in favor of alternating instead of direct-current operation. The weakness of the alternating-current system, however, lies in the possibility of disabling a number of signals due to breakage or crosses of the two wires constituting the signal supply mains.

High voltage wires are not desirable on telegraph pole lines, but if conditions permit the use of low voltage, say 500 volts, they may be placed on poles with other wires, but should be on the top cross-arm, so that other wires, which break more readily, may not fall upon and cross them. A good arrangement is to have an independent pole line for the signal mains if a high-tension pole line is not available, and make the construction so substantial that it will not break down. The stations supplying current to the mains should be equipped with apparatus in duplicate. By thus treating the equipment which is common to a number of signals with the same care that is bestowed upon electric power and lighting systems, this part of the signal system could be made reasonably reliable.

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CHAPTER VIII

AUTOMATIC BLOCK SIGNALING—ALTERNATING CURRENT

DOUBLE-RAIL RETURN SYSTEM
DIRECT-CURRENT TRAIN PROPULSION

SIGNALING by the double-rail return system, in which both rails are used as return conductors for the train propulsion current simultaneously with the alternating-current block signaling current, is accomplished by the use of balanced inductive bonds connected across the rail insulations at the ends of the blocks. These bonds offer impedance to the passage of the signaling current, but not to an appreciable extent to the passage of the return train propulsion current. stop. A good form of reactance bond is that shown

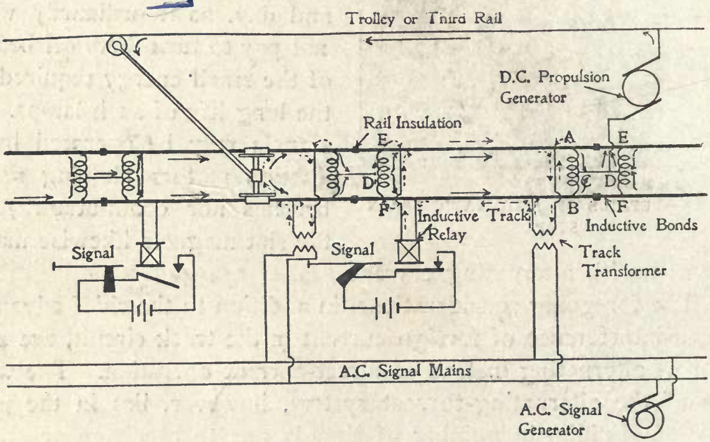


FIG. 73—TRACK AND SIGNAL CIRCUITS
The dotted and full line arrows show the direction of the alternating and direct currents respectively.

in Fig. 73, in which the propulsion current passes from the rails into the ends of the coil at *A* and *B* and out at *C*, the middle of the coil of the bond, or in at the middle at *D* and out at the ends *E* and *F*. With equal amounts of return current in each rail the magnetizing effect on the iron is nil, but the signaling current, which flows from end to end of the bond (*A* to *B*), sets up a reactance, which maintains a difference of potential between the rails sufficient to operate the inductive track relay. The propulsion current is shown by full arrows and the signaling current by dotted arrows. Unlike the single-rail return system, the drop of voltage in each rail due to the

propulsion return current is, under favorable conditions, nearly equal, so that little or no propulsion current flows through the track transformer at one end or the track relay at the other end of the block. For this reason it is not necessary to interpose resistances between the track and this apparatus, nor to connect an inductive shunt across the relay coils. The iron of the track transformer has a closed magnetic circuit, that is, it is without an air gap.

Adjustable magnetic leakage filler blocks are inserted between the primary and secondary coils, causing a drop of voltage and

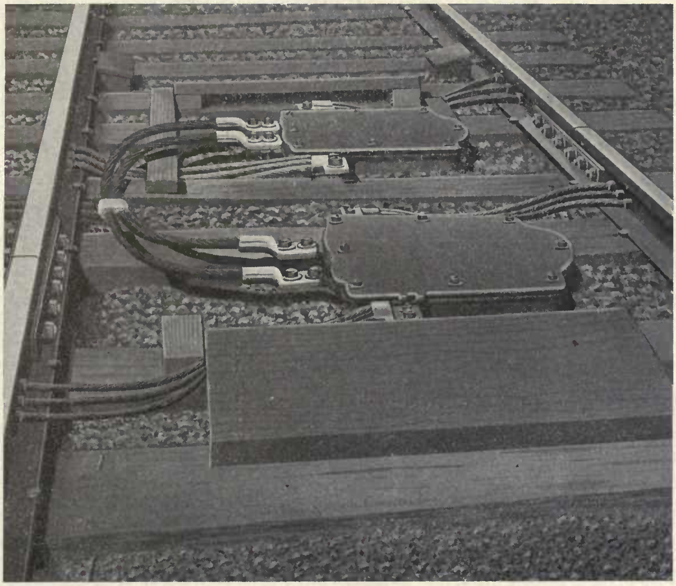


FIG. 74—INDUCTIVE BONDS
The wooden covers are removed to show details of bonds.

limiting the current when the transformer is short-circuited by a train in the block.

It is probably never true in practice that equal amounts of propulsion current are carried by each rail of a block owing to unequal resistance due to defective bonding and the like. The difference in the amount of current in the two rails is called unbalancing current because its effect on the iron of the bond is not neutralized by an equal amount of current through the opposite half of the bond.

It should be noted here that a bond as a unit consists of the coil and iron within a cast iron case included between *A* and *B*, and an-

other like bond between *E* and *F*. The middle points of their coils are connected by a conductor *C D*.

Properly the inductive bond around each rail insulation consists of one-half of each bond as *A C D E* and *B C D E*.

In order to reduce the magnetizing effect of the unbalanced propulsion current on the bond *A B* or *E F* so that its reactance to the alternating signaling current will undergo but little change, an air gap is introduced into the iron of the bond. Obviously, the reluctance of this air gap considerably reduces the reactance to the alternating signaling current, thus requiring additional signaling current through the bond to maintain the necessary difference of alternating-current potential between the rails.

The increased current required by the bond *E F* at the relay end of the block causes additional alternating-current drop in the rails, which in turn necessitates a higher voltage and more current from the track transformer. Thus the bond *A B* at the transformer

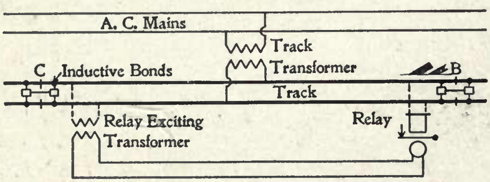


FIG. 75

receives more current than it otherwise requires in order that the bond *E F* at the relay receive enough to maintain sufficient voltage to operate the track relay. Hence the signal mains must have sufficient copper and the generating plants be of sufficient capacity to maintain these conditions.

For the above reasons it is occasionally desirable to locate the track transformer in the middle and use a track relay at each end of the block, or an equivalent, and in some respects better arrangement is to use but one track relay having wire-wound field and armature and energize the field from one end of the track circuit and the armature from the other through a small step-up transformer and line wires. (See Fig. 75.) It will be seen that the design of, and power required for, a signal system depends upon the kind of maintenance which a railroad company gives the return conductors, the rails, in the way of bonding; for if the bonding is good, with a resulting equal amount of current in each rail, the air gap in the bonds may be made

very small. Such desirable conditions mean a saving in line copper, capacity of generating plant and operating expenses, or if conditions warrant it, a considerable increase in the workable length of track circuit. Ordinarily railroad companies are not willing that even very defective bonding should result in a danger signal with the block unoccupied, so that alternating-current signal plants are now, and more will be, in service in which the inductive bonds have unbalancing capacities equal to perhaps one-half or more of the total propulsion load. The importance of this feature is perhaps more clearly seen when compared with the simplicity and economy of the single-rail system of alternating-current signaling on direct-current roads,

FIG. 76—SIGNALS ON ELECTRIFIED RAILROAD
Inductive bonds are shown on each track between the rails.

and especially on steam roads. In this connection it will be noted that in a general way, the double-rail return system is preferable to the single-rail system in cases where the blocks are long, hence requiring relatively few inductive bonds, and where the running rails are the sole conductors for the return of the propulsion current, whereas the single-rail scheme is to be preferred for the opposite conditions, a notable illustration of which is the Interborough Rapid Transit System in New York City.

The current taken by the track relays and the inductive bonds, has considerable lag owing to the highly inductive nature of the apparatus, while that which leaks from rail to rail, due to the comparatively low resistance of the ballast and ties, has a power-factor of unity.

The frequency ordinarily used is 25 cycles. The track relay is of the induction type and does not respond to direct current.

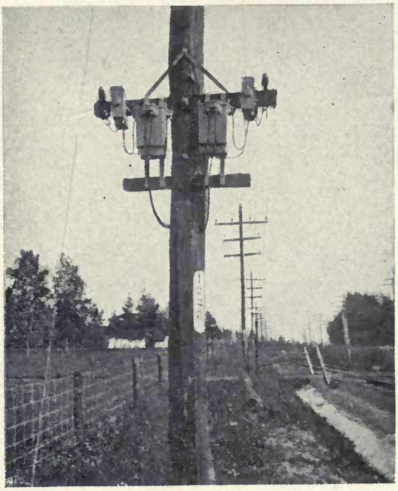


FIG. 77—TRANSFORMERS

Used to step down voltage from high tension signal mains to low voltage signal circuits.

ALTERNATING-CURRENT PROPULSION

The double-rail return system of alternating-current roads is very similar to that for direct-current roads, except that the inductive bonds have no air gaps and are of smaller capacity, and the track relays are of a somewhat different type.

As the propulsion current has a frequency of 25 cycles or less, the signaling current is given a frequency of 60 cycles in order that a track relay may be used which responds to a current of the latter frequency and not to the former. In other words, the relay operates selectively on frequency and, of course, does not respond to any foreign direct current which may be present.

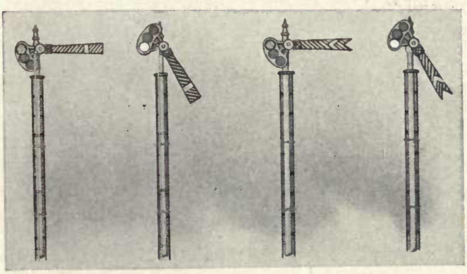
This system is now in service on the New York, New Haven and Hartford railroad, and gives satisfactory results.

CHAPTER IX

THE LANGUAGE OF FIXED SIGNALS

THE previous chapters have dealt with the principles and with the actual details of the apparatus used in operating the various forms of signal apparatus. To the railway employes, to the passengers and to the casual observer the signal indications themselves are the important features of a signal system. The actual mechanisms used to accomplish the desired results are not of especial interest so long as they give the positive indications desired relative to the condition of the tracks and positions of trains. Two kinds of indications are used, one for day and one for night service. The semaphore arm, in various positions, is used in the daytime. A light, mounted behind a spectacle attached to the semaphore and holding colored roundels is used at night. The semaphore signal is primarily a position signal, yet in many systems the shape and color of the signal blade must also be considered in order to properly interpret the various indications displayed.

WHITE RED GREEN YELLOW BLACK



STOP PROCEED CAUTION PROCEED

HOME SIGNAL DISTANT SIGNAL

FIG. 78—ONE-ARM, HIGH, TWO-POSITION INTERLOCKED TRACK SIGNALS

MEANINGS

Home Signal.

Stop—Remain stopped; route is not ready for train to proceed.

Proceed—Route is ready for train to proceed.

Distant Signal

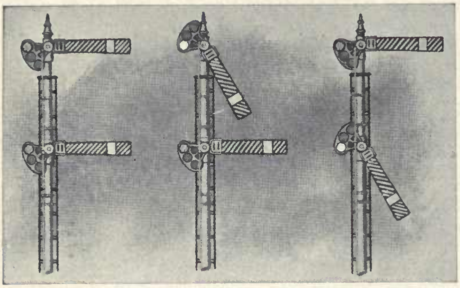
Caution—Prepare to stop at next home signal.

Proceed—Expect to find next home signal in proceed position.

The oldest and most common types of interlocked track signals are shown in Fig. 78. The two semaphore arms on the left have square ends and are painted red with a white band near the end. The night indications show a red light when the the blade is horizontal and a white light when the blade is inclined.

The semaphore arms on the right are called distant signals and have notched ends. They are painted green with a white V-shaped band near the end. At night, with the blade horizontal, a green light would appear and with the blade inclined a white light.

For many years red and green have been used on railroads to indicate danger and caution, yet on most roads they still paint their signal blades these colors and then educate their trainmen so that they understand that it is the position of the blade and not its color which really counts.



STOP PROCEED "A" PROCEED "B"

FIG. 79—TWO-ARM, HIGH, TWO-POSITION INTERLOCKED HOME TRACK SIGNALS

MEANINGS

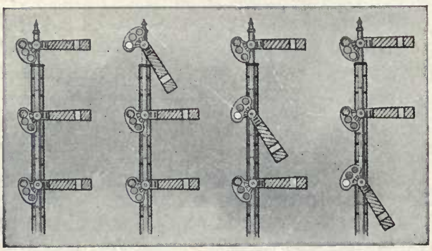
Stop—Remain stopped; no routes ready for train to proceed.

Proceed "A"—Superior route is ready for train to proceed.

Proceed "B"—One inferior route is ready for train to proceed.

If only two positions are used, it is evident that in the case of the distant signal, the blade must be painted a different color or have a different shape, or both, in order that its day indications may be distinguished from those of the home signal.

The home signal shown in Fig. 78 would be used only to govern movements over a track having no facing point switches for diverging routes, but this track may have one or more derails or trailing switches, which must be properly set and locked before the signal can be cleared.



STOP PROCEED "A" PROCEED "B" PROCEED "C"

FIG. 80—THREE-ARM, HIGH, TWO-POSITION INTERLOCKED HOME TRACK SIGNALS

MEANINGS

Stop—Remain stopped; no routes ready for train to proceed.

Proceed "A"—Main route is ready for train to proceed.

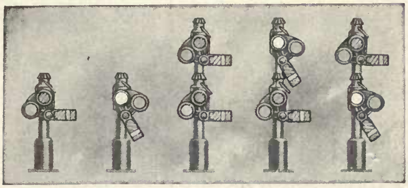
Proceed "B"—Second main route is ready for train to proceed.

Proceed "C"—One inferior route is ready for train to proceed.

In Fig. 79 are shown two-arm, high, two-position interlocked home track signals. The blades are all painted red with a white band, and the night indications are either red or white, depending on whether the blades are horizontal or inclined. These signals are used where there is one superior or main route and two or more inferior or branch routes. The lower arms govern movements to any of the inferior routes. Many roads never

use more than two arms on any post, although there may be more than one superior route. Some roads always place two arms on one post although there may be no diverging routes. This is done for uniformity and in this case the lower arm would be immovable.

In Fig. 80 are shown the indications obtainable by the use of three-arm two-position interlocked home track signals. The blades are all painted red with white bands, and the night indications are either red or white. This arrangement of signals should be employed only at the junctions of two main and one or more inferior routes. The use of this type of signal is constantly becoming less frequent, and the necessity for its use is met by another development to be described later.



STOP "A" PROCEED "A" STOP "B" PROCEED "B" PROCEED "C"

FIG. 81—ONE- AND TWO-ARM, TWO-POSITION DWARF INTERLOCKED HOME TRACK SIGNALS

MEANINGS

Stop—Remain stopped; route is not ready for train to proceed.

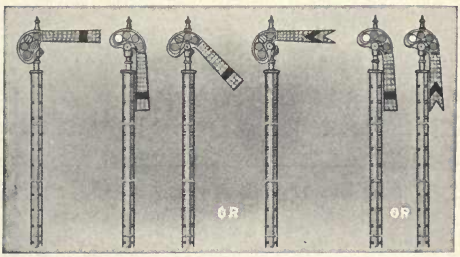
Proceed "A"—Route is ready for train to proceed.

Stop "B"—Remain stopped; no routes are ready for train to proceed.

Proceed "B"—Superior route is ready for train to proceed.

Proceed "C"—One inferior route is ready for train to proceed.

Dwarf track signals are used on main tracks to govern movements against the regular direction of traffic and on other tracks to govern all movements. The different indications of one and two-arm two-position dwarf signals are shown in Fig. 81. The blades are red with a white band and the night indications either red or white. Since all dwarf signals govern movements which should be made at low speed, the two-arm type is very seldom used. However, track conditions sometimes require their use in



STOP PROCEED CAUTION PROCEED
HOME SIGNAL DISTANT SIGNALS

FIG. 82—ONE-ARM, HIGH, 90 DEGREE TRAVEL, TWO-POSITION INTERLOCKED TRACK SIGNALS

MEANINGS

Home Signal

Stop—Remain stopped; route is not ready for train to proceed.

Proceed—Route is ready for train to proceed.

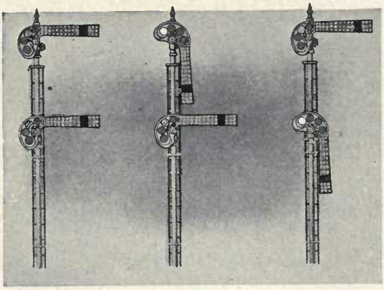
Distant signals

Caution—Prepare to stop at next home signal.

Proceed—Expect to find next home signal in proceed position.

order that one arm may be used to govern one particularly important route only.

The signals shown in Fig. 82 are the equivalent of those shown in Fig. 78, the only difference being that the sweep of the arm is 90 degrees instead of 60 degrees, and the blades are painted a neutral color, such as yellow. Two types of distant signals have been used as shown. The distant blade with the square end was the first consistent development of the practice of giving both home and distant signal indications distinctly without any regard to color or shape of blade.



STOP PROCEED "A" PROCEED "B"

FIG. 83—TWO-ARM, HIGH, 90 DEGREE TRAVEL, TWO-POSITION INTERLOCKED HOME TRACK SIGNALS

MEANINGS

Stop—Remain stopped; no routes are ready for train to proceed.

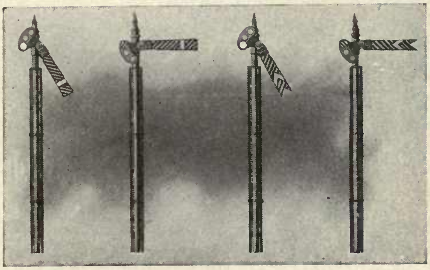
Proceed "A"—Superior route is ready for train to proceed.

Proceed "B"—One inferior route is ready for train to proceed.

The types of signals shown in Fig. 83 are the equivalent of those shown in Fig. 79, the only difference being in the sweep of the arms and the color of the blades.

All of the signals just described indicate only the condition of the tracks as far as the position of interlocked switches and derails is concerned. They do not indicate the presence of trains or whether the interlocked cross-overs and turn-outs are so constructed that the movements over them can be safely made at a moderately high speed.

Block signals are used to indicate the presence or absence of trains between definite points. Automatic block signals usually indicate more than this because, in addition to the other meanings, they indicate the condition of the track as far as broken rails or misplaced switches are concerned. During the past few years when the railroads have been having so much trouble on account of broken rails, automatic block signals have been a great protection. On one road as many as a dozen cases of broken rails in one month were indicated by their automatic block signals and serious wrecks were doubtless prevented.



PROCEED STOP PROCEED CAUTION
HOME SIGNAL DISTANT SIGNAL

FIG. 84—ONE-ARM, HIGH, TWO-POSITION AUTOMATIC HOME AND DISTANT BLOCK SIGNALS

MEANINGS

Home Signals

Proceed—Block is in condition for train to proceed.

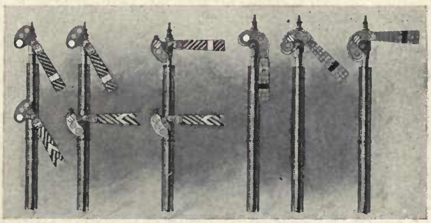
Stop—Stop and wait prescribed time, then proceed with caution, expecting to find train in block, misplaced switch or broken rail.

Distant Signal

Proceed—Expect to find next home signal in proceed posititon.

Caution—Prepare to stop at next home signal.

In appearance automatic block signals of the one-arm type shown by Fig. 84 cannot be distinguished from the interlocked signals such as those shown in Fig. 78, although their meaning is different. This similarity has caused some roads to place a marker, such as an illumi-



PROCEED STOP PROCEED STOP
"A" "B" "A" "B"

FIG. 85—TWO-ARM, HIGH, TWO-POSITION AND ONE-ARM, HIGH, THREE-POSITION AUTOMATIC HOME AND DISTANT BLOCK SIGNALS

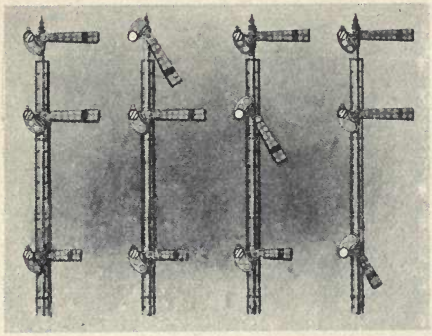
MEANINGS

Proceed "A"—Block is in condition for train to proceed. Expect to find next home signal in proceed position.

Proceed "B"—Block is in condition for train to proceed. Prepare to stop at next home signal.

Stop—Stop and wait prescribed time, then proceed with caution expecting to find train in block, misplaced switch or broken rail.

nated letter *A*, on each of their automatic block signal masts, so that when an engineer comes to a stop signal, he can, after making the stop, readily distinguish between the interlocking and block signals. Later developments in the art have led to further refinements in this particular.



STOP PROCEED "A" PROCEED "B" PROCEED "C"

FIG. 86—THREE-ARM, TWO-POSITION INTERLOCKED HOME TRACK AND SPEED SIGNALS

MEANINGS

Stop—Remain stopped. No routes are ready for train to proceed.

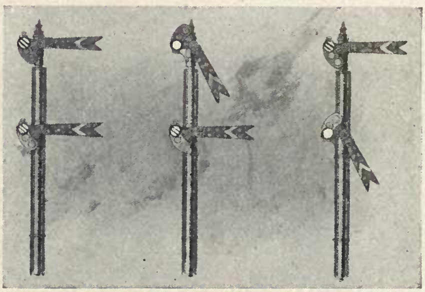
Proceed "A"—A high speed route is ready for train to proceed.

Proceed "B"—A moderate speed route is ready for train to proceed.

Proceed "C"—A low speed route is ready for train to proceed.

The home and distant signals on separate posts are used in overlap block systems, in single track block systems and in double track block systems where the blocks are unusually long.

Automatic signals are more commonly used on double track roads with heavy traffic and the blocks are short, so that the home and distant signals are frequently mounted on the same post or the equivalent three position signal shown in Fig. 85, is used.



CAUTION PROCEED "A" PROCEED "B"

FIG. 87—TWO-ARM, HIGH, TWO-POSITION INTERLOCKED DISTANT TRACK AND SPEED SIGNALS

MEANINGS

Caution—Prepare to stop at next home signal.

Proceed "A"—Expect to find next high speed home signal in proceed position.

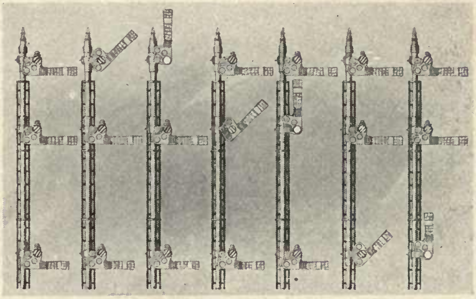
Proceed "B"—Expect to find next moderate speed home signal in proceed position.

All of the signals previously described are types in common use. They have not, however, been found adequate for the conditions which have recently been arising. It has been found necessary to increase the capacity of roads by getting the trains over them faster. High speed turnouts and crossovers have been put in, so that this can be accomplished. On one road it is quite common practice to put in a crossover on each side of a sub-

urban passenger station, so that while a local train is making the station stop, an express can come up behind and run around it at a speed of forty miles per hour.

Since many turnouts cannot be taken at even moderately high speeds, a new requirement is that interlocked signals shall also indicate speed as well as tracks and hence the development shown in Fig. 86. These signals require the corresponding distant signals shown in Fig. 87.

A further requirement is that interlocked signals shall also indicate the condition of the block as well as the tracks and speed. This led to the development shown in Fig. 88. At present this is being used on only one road, but is being seriously considered for general adoption by other leading roads. This scheme also provides for a distinguishing feature between automatic block and interlocked signals.

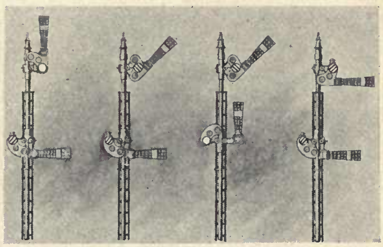


Stop Proceed "A" Proceed "B" Proceed "C" Proceed "D" Proceed "E" Proceed "F"

FIG. 88—THREE-ARM, HIGH, 90 DEGREE UPWARD TRAVEL, THREE-POSITION INTERLOCKED TRACK, SPEED AND BLOCK SIGNALS

MEANINGS

Stop—Remain stopped. Route or block not ready for train to proceed.
Proceed "A"—Proceed on high speed track. Prepare to stop at next home signal.
Proceed "B"—Proceed on high speed track. Expect to find next home signal in proceed position.
Proceed "C"—Proceed on moderate speed track. Prepare to stop at next home signal.
Proceed "D"—Proceed on moderate speed track. Expect to find next home signal in proceed position.
Proceed "E"—Proceed with extreme caution on low speed track.
Proceed "F"—Proceed on low speed track.



PROCEED "A" PROCEED "B" PROCEED "C" STOP

FIG. 89—TWO-ARM, HIGH, 90 DEGREE UPWARD TRAVEL, THREE-POSITION AUTOMATIC BLOCK AND INTERLOCKING DISTANT SIGNALS

MEANINGS

Proceed "A"—Proceed. Expect to find next high-speed home signal in caution or proceed position.
Proceed "B"—Proceed. Prepare to stop at next home signal.
Proceed "C"—Proceed. Expect to find next moderate-speed home signal in caution or proceed position.
Stop—Stop and wait the prescribed time, then proceed with caution expecting to find train in block, misplaced switch or broken rail.

All interlocked signals have the arms and lights, one vertically below another, while the automatic block signals have the arms and lights staggered as shown in Fig. 89. On approaching an interlocking, the block signals are also used as distant signals for the interlocking home signals. Where the block indication only is given, the lower arm is fixed in the horizontal position and is really only a marker.